3 Building Envelope

3.0 Summary

This chapter discusses the requirements of the Energy Efficiency Standards *(Standards)* as they apply to the building envelope (walls, roofs, floors, windows, skylights, etc.). It addresses common questions asked by building envelope designers, plan checkers and inspectors. Additional information is found in Chapter 2: Scope and Application and Chapter 6: Special Topics.

The Introduction section (3.1) explains the basic envelope compliance approaches and provides a tutorial on many of the concepts necessary for understanding the envelope requirements. The Envelope Design Procedures section (3.2) discusses the requirements of the *Standards* as they concern a designer. The Envelope Plan Check Documents section (3.3) explains the compliance forms and the information, which must be included on the plans by the designer prior to being checked by the building department.

3.1 Introduction

The design of the building envelope is generally the responsibility of an architect, although it may be done by a contractor, an engineer, or some other person. The designer is responsible for making sure that the building envelope complies with the *Standards*. Likewise, the building official is responsible for making sure that the building envelope is designed and built in conformance with the *Standards*. This chapter is written for the designer and the building official, as well as other specialists who participate in the design and construction of the building envelope.

3.1.1 Envelope Compliance Approaches

The envelope requirements contain more than one approach to compliance in order to allow flexibility to accommodate the wide variety of nonresidential buildings. The characteristics, advantages and disadvantages of each method are introduced in this Section. These requirements are in addition to the envelope mandatory measures, which apply regardless of the compliance approach (Section 3.2.1).

A. Prescriptive Approach (§143)

Under the prescriptive approach there are two alternatives for envelope compliance: the Envelope Component Approach and the Overall Envelope Approach.

Envelope Component Approach vs. Overall Envelope Approach

Envelope Component Approach (§143(a)) is the simpler and more direct of the two prescriptive compliance approaches. It consists of a specific requirement for each envelope component: roofs and ceilings, exterior walls, demising walls, external floors and soffits, windows, and skylights.

There are no trade-offs between components. If all the requirements are met, the envelope complies. If even one component does not meet its individual requirement, the envelope does not comply.

Under the Envelope Component Approach, each opaque assembly has to meet a minimum insulation level. Each glazing component has to meet insulating and solar heat gain coefficient (SHGC) values, and there is an upper limit on glazing area. If these requirements are met, the building complies with the *Standards.* See Section 3.2.2 for a more complete discussion of the Envelope Component Approach.

Overall Envelope Approach (§143(b)) treats envelope components as a system. This offers the ability to make trade-offs between envelope components, which is the principal advantage of this approach.

The Overall Envelope Approach uses two measures of envelope performance: the overall heat loss and the overall heat gain. The overall heat loss is a measure of the insulating quality of all the envelope components together, including both opaque and glazing surfaces. The overall heat gain considers insulation, solar heat gain through windows and skylights, and the reflectance of the roof.

The code baseline for both heat gain and heat loss is determined using the insulation and solar heat gain coefficient values from the Envelope Component Approach, and applying them to the envelope surface areas of the proposed building (with some limits on glazing area). The proposed design's overall heat loss and heat gain are calculated based on the installed insulation, fenestration performance, and roof surface properties. If the proposed heat loss and heat gain are no higher than the standard heat loss and heat gain, then the envelope complies. See Section 3.2.3 for a more complete discussion of the Overall Envelope Approach.

B. Performance Approach (§141)

The other option for envelope compliance is the Performance Approach. It may be used for either envelope-only compliance or may include lighting and mechanical system compliance when these systems are permitted at the same time. When the performance approach is used for the envelope only, the computer model deals with the energy efficiency of the entire envelope under both heating and cooling conditions. This means that trade-offs can be made between all envelope components. The computer analysis is much more sophisticated and can account for more subtle energy effects due to surface orientation and hourly changes in the outside temperature. If the envelope compliance is combined with other parts of the building, then more trade-offs can be made, such as increasing envelope efficiency in order to allow more lighting power or a less efficient mechanical system. See Sections 3.2.4 and 6.1 for a more complete discussion of the performance approach.

3.1.2 Basic Envelope Concepts

In order to understand the particulars of each of the compliance approaches, several key definitions and energy concepts must be presented. In addition, before proceeding to the discussion below, the reader should be familiar with the various conditioned space definitions (see Section 2.1.1A).

A. Definitions (§101(b))

Atrium is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning, or other equipment which is enclosed space and not defined as a mall. The definition of an atrium is significant because of the skylight area requirements. The key concept is that the atrium is an opening through floor levels, not counting openings needed for equipment. Malls are not considered as atria. The skylight requirements are different when the atrium is over 55 feet high. According to the UBC, an atrium over 55 feet high must have a mechanical ventilation system (particulars defined in the UBC), so the higher skylight allowances for atriums only apply when the ventilation system is required. In questionable cases, the determination of atrium height will be made by the building department, and will follow UBC guidelines.

Cool Roof *is a roofing material with high solar reflectance and high emittance that reduces heat gain through the roof.* To qualify as a cool roof, concrete or tile roofs must have an initial reflectance greater than 0.40 and other roofs must have an initial reflectance greater than 0.70. All cool roofs must have an emittance greater than 0.75. Cool roofs are typically white and have a smooth texture. Commercial roofing products that qualify as cool roofs are either tiles or coatings. Tiles are made of light colored concrete or clay with high reflectance and emittance. Painted metal roofing products are also eligible for cool roof credits (note that the minimum coating thickness requirement does *not* apply to these products). Coatings are applied to single ply or other material to increase the reflectance and emittance of that material. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance assures that when the roof does warm up, its heat can escape through radiation to the sky.

Demising Partitions *are barriers that separate conditioned space from enclosed unconditioned space.* The only difference between an exterior partition and a demising partition is that the demising partition has enclosed unconditioned space on one side, rather than outdoor space. The demising partition could adjoin, for example, an unconditioned warehouse, an enclosed garage, or an unconditioned vestibule. The distinction between exterior and demising walls is made because demising walls have their own requirements and they are not treated the same way as exterior partitions in the energy calculations.

Demising Wall *is a wall that is a demising partition.* A wall is the only case where a demising partition is treated differently from an exterior partition (there are special insulation requirements (§143(a)3 and §118(e)). Glazing area in demising walls is not limited (§141(a) and §143(a)5A).

Display Perimeter *is the length of an exterior wall in a B, F-1 or M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.* This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to public at large (no obstructions, limits to access, or intervening non-public spaces). The display perimeter is used for a special calculation of window area (§143(a)5A). Demising walls are not counted as part of the display perimeter.

Effective Aperture (See Chapter 5).

Exterior Door *is a door through an exterior partition.* The exterior door area is used only in calculating the gross exterior wall area; there are no R-value, U-factor or area requirements for exterior doors (§143(a)7). Note that if the door has glazing in excess of one-half of the door area, it should be treated as a window or a skylight (depending on slope). See discussion of **Window Area** below for the measurement of glazing area in doors.

Exterior Floor/Soffit *is a horizontal exterior partition, or a horizontal demising partition, under conditioned space.* It is measured using exterior dimensions. Note that the conditioned space can be directly or indirectly conditioned space, and it can adjoin either ambient air or enclosed, unconditioned space. Also note that, unlike the residential *Standards,* slabs-on-grade are not considered exterior floors because they do not separate conditioned space from ambient air or unconditioned space (see discussion of **Exterior Partition** below). A floor over a ventilated crawl space or a parking garage would be an exterior floor. Likewise, in a conditioned attic space, the soffit of an overhanging eave would be considered an exterior floor/soffit because it has unconditioned space below (see Figure 3-1).

Exterior Partition *is an opaque, translucent, or transparent solid barrier that separates conditioned space from ambient air or space that is not enclosed.* It separates conditioned space (including **Indirectly Conditioned Space**) from the outdoors or from spaces that are not enclosed. The terms partition and barrier are used as generic descriptors of any envelope element, including windows, soffits, skylights, metal doors, walls, roofs, etc.

Exterior Roof/Ceiling *is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below, and that is not* *an exterior door or skylight.* This means that the space above the roof or ceiling can be either ambient air or enclosed, unconditioned space. In either case, the envelope requirements for roofs/ceilings apply. An example of an enclosed, unconditioned space would be a ventilated attic or mechanical room. Another would be the ceiling of a conditioned office built within a taller, unconditioned warehouse space (see Figure 3-2).

Exterior Wall *is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane. An exterior wall or partition is not an exterior floor/soffit, exterior door, exterior roof/ceiling, window, skylight, or demising wall.* This leaves only the opaque wall surfaces defined as exterior walls. They separate directly or indirectly conditioned space from the outdoors. Note that they do not include demising walls, which adjoin enclosed unconditioned space.

Exterior Wall Area *is the area of the opaque exterior surface of exterior walls.* It is measured using exterior dimensions. This area does not include windows or doors.

Fenestration or Glazing **Product** (same definition) *is any transparent or translucent material plus any sash, frame, mullions and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one-half of the door area.*

Figure 3-1– Requirements for Floor/Soffit Surfaces

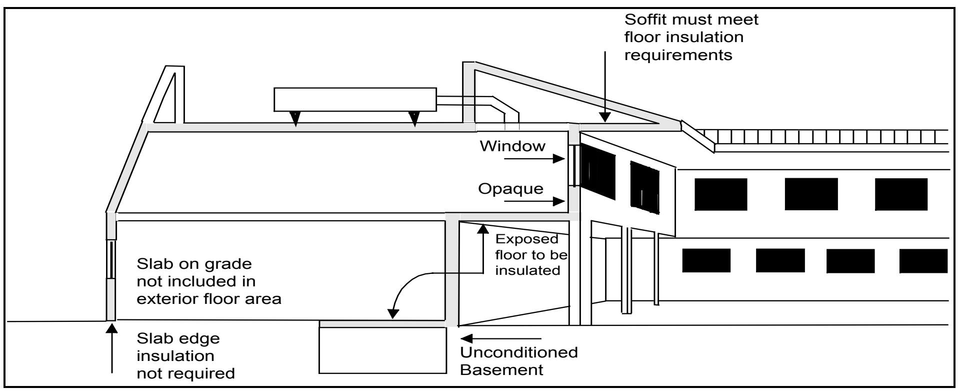
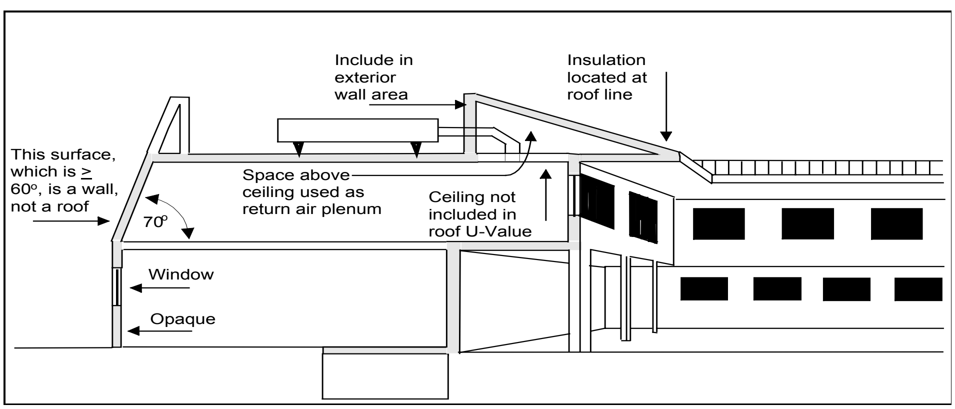


Figure 3-2– Requirements for Roof/Ceiling Surfaces



Field-Fabricated Fenestration Product or Exterior Door *is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits and curtainwalls).* The U-factor and solar heat gain coefficient are determined from the default table (see Table 3-10 and Table 3-12).

Fenestration System *means a collection of fenestration products included in the design of a building. (See "fenestration product").*

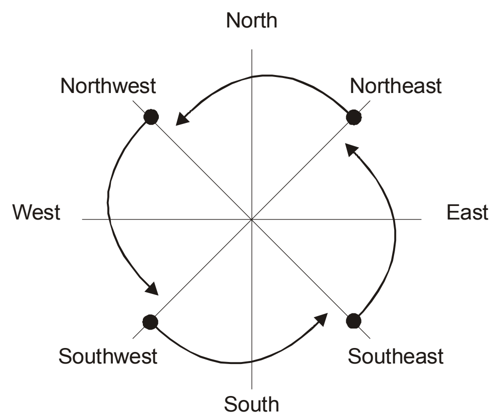
Floor/Soffit Type is a floor/soffit assembly having a specific heat capacity, framing type, and U-factor.

Gross Exterior Roof Area *is the sum of the skylight area and the exterior roof/ceiling area.* Note that this does not include exterior door areas, such as roof hatches. Roof areas are measured using outside dimensions.

Gross Exterior Wall Area *is the sum of the window area, door area, and exterior wall area.* This area is only used to calculate limits on exterior window area.

Orientation (North, East, South and West) see Glossary (Appendix G) definitions of **North-facing, East-facing, etc.** The *Standards* make this distinction because solar heat gain differs by orientation, causing envelope energy flows to vary with orientation. In general, any orientation within 45° of true north, east, south or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-3 indicates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an *east-facing* surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

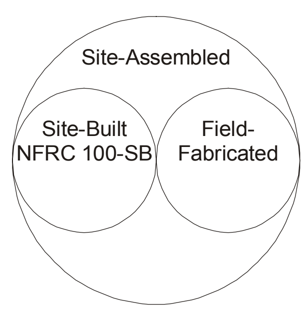
Figure 3-3– Surface Orientations



Relative Solar Heat Gain is the ratio of solar heat gain through a fenestration product (corrected for shading from overhangs) to the incident solar radiation. If there are no overhangs, the RSHG is equal to the SHGC. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted or convected into the space. RSHG is used with the building envelop trade-off method of compliance.

Site-Assembled Fenestration *includes both field-fabricated fenestration and site-built fenestration.* For more information, see the definitions for **Field-Fabricated Fenestration Products** and **Site-Built Fenestration Products**.

Figure 3-4– Fenestration Definitions

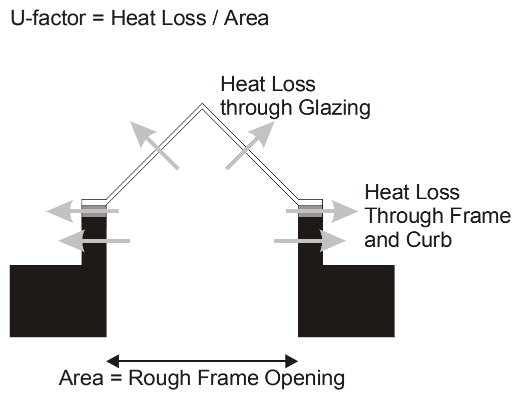


Site-Built Fenestration Products *are fenestration products designed to be field-glazed or field assembled units comprised of specified framing and glazing components. Site-built fenestration is eligible for certification under NFRC 100-SB, and may include both vertical glazing and horizontal glazing.* Examples of site-built products are storefront systems, curtain walls, atrium roof systems and other similar glazing systems. The key distinction between site-built and field-fabricated fenestration is that the latter is not practical to rate since the frames are being constructed at the building site out of raw materials that were not intended to be part of a specific fenestration product.

Skylight *is glazing having a slope less than 60 degrees from the horizontal with conditioned space below*. See discussion of **Slope** below.

Skylight Area *is the area of the surface of a skylight, plus the area of the frame, sash, and mullions.* The rough framed opening is used in the NFRC U-factor ratings procedure; it is also the basis of the default U-factors in Table B-14 in Appendix B. For skylights, the U-factor represents the heat loss per unit of rough framed opening (the denominator). However, the heat loss (the numerator) includes losses through the glazing, the frame, and the curb (see Figure 3-5). Site-built skylights are often used for atrium roofs, malls, and other applications that need large skylights. In such cases the skylight area is the surface area of the glazing and frame/curb (not the area of the rough framed opening), regardless of the geometry of the skylight (i.e., could be flat pyramid, bubble, barrel vault, or other three-dimensional shape).

Figure 3-5– Skylight Area

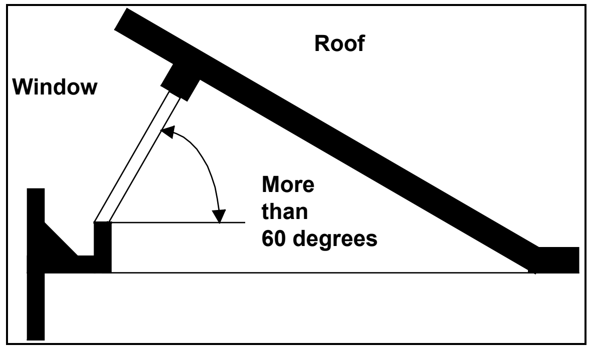


Skylight Type *is a type of skylight assembly having a specific solar heat gain coefficient, and U-factor, whether glass mounted on a curb, glass not mounted on a curb or plastic (assumed to be mounted on a curb).* For determining compliance with the *Standards*, there are three skylight types, glass with curb, glass without curb and plastic with curb.

There are two ways that skylights can be mounted into a roof system, either flush-mounted or curb-mounted. In order to create a positive water flow around them, skylights are often mounted on "curbs" set above the roof plane. These curbs, rising 6 to 12 inches (15 to 30 centimeters) above the roof, create additional heat loss surfaces, right where the warmest air of the building tends to collect.

Slope is used to distinguish between walls and roofs (see **Exterior Roof/Ceiling** definition above). If an exterior partition has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall (see Figure 3-6). This definition extends to fenestration products, including the windows in walls and any skylights in roofs. In Figure 3-6, the window is considered part of the wall because the slope is over 60 degrees. Where the slope less than 60 degrees, the glazing indicated as a window would be a skylight.

Figure 3-6– Slope of a Wall or Window (Roof or Skylight slope is less than 60°)



Solar Heat Gain Coefficient (SHGC) *is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.*

Wall Type *is a wall assembly having a specific heat capacity, framing type, and U-factor.*

Well Index (see Section 5.1.1A)

Window *is glazing that is not a skylight.* Note that the window includes any sash, framing, mullions or dividers.

Window Area *is the area of the surface of a window, plus the area of the frame, sash, and mullions.* As a practical matter, window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be a bit larger than the formally defined window area. Use the rough opening area, except for a window in a door. In this case, use the area of the frame that holds the glazing material. For unframed glass doors, use the rough opening of the entire door.

Window Type *is a window assembly having a specific solar heat gain coefficient, relative solar heat gain, and U-factor.*

Window Wall Ratio *is the ratio of the window area to the gross exterior wall area.* Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls. Glazing area in demising walls has no limit and any glazing in demising walls is not counted as part of the exterior wall/window ratio.

B. Insulation R-value (§143(a))

Thermal Resistance (R) is the resistance of a material or building component to the passage of heat in (hr x ft^2 x °F)/Btu.

The R-value of an insulation material is a measure of its thermal resistance. The higher the R-value, the greater the thermal resistance or the better the insulating value of the material. The thicker the material, the greater its R-value. R-values are used in the Envelope Component Method as minimum efficiency requirements. They are also used as part of the calculation of the U-factors of opaque building envelope assemblies. See the following Sections (C through F) on U-factors for more information on these calculations.

Most types of insulating material used in California must be certified by the manufacturer as meeting the California Quality Standards for Insulating Material. See §118 for a more complete description of these requirements.

C. Overall Assembly U-factor (§143(b))

U-factor is the overall coefficient of thermal transmittance of a construction assembly in Btu/(hr x ft^2 x °F), including air film resistance at both surfaces.

The U-factor describes the rate of heat flow through a building surface. The *Standards* specify U-factor limits, which translate into minimum insulation requirements for the envelope. The U-factor tells how many Btu (British thermal units) of heat energy will pass through one square foot of surface area in an hour, for every degree of temperature difference, between inside and outside air. The higher the temperature difference, the more heat will flow. It follows, then, that lower U-factors mean smaller quantities of heat flow, less winter heat loss and less summer heat gain. U-factors are always calculated to three significant digits.

The U-factor calculation varies depending on the composition of the wall, roof, or other assembly under consideration. The variations are discussed in the following sections.

In addition to the insulating properties of the materials that make up a construction assembly, such as a wall, thin layers of air cling to the surface of the assembly. These air films, as they are called, add to the insulating value of the assembly. They are accounted for in the U-factor, and can have a significant effect on envelope compliance, especially for uninsulated assemblies.

Standard air film R-values are to be used for compliance purposes (see the following subsections for discussion of U-factor calculations). The standard values assume that the interior air film is in still air, and that the exterior air film is in a 15 mile per hour breeze, which considerably reduces the thickness and insulating value of the air film. Table 3-1 lists the standard air film R-values.

The following subsections describe how the U-factors of various envelope components are calculated. These U-factors are used to demonstrate compliance with the envelope *Standards*.

Note: Weight averaging of assemblies requires a U-factor. R-values cannot be weight averaged.

D. Wood Frame U-factors (§141(c)4.B)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.* Wood-framing is common in smaller nonresidential buildings, and is known by such names as wall stud, roof rafters and floor joists. Wood framing uses small dimension lumber as the structural elements, typically spaced on 16 inch or 24 inch centers. The cavities between the framing members typically are filled with insulation.

Table 3-1 - Standard Air Film R-values

	Wall	Roof Flat [2]	Roof 45° Angle [3]	Floor
Air Films [1]				
Inside	0.68	0.61	0.62	0.92
Outside	0.17	0.17	0.17	0.17
Air Spaces [4]				
0.5 inch	0.77	0.73	0.86	0.77
0.75 inch	0.84	0.75	0.81	0.85
1.5 inch	0.87	0.77	0.80	0.94
3.5 inch [5]	0.85	0.80	0.82	1.00

NOTE: Values from ASHRAE Handbook of Fundamentals, 1993 edition, Chapter 22, Tables 1 & 2.

[1] Assumes a non-reflective surface emittance of 0.90 and winter heat flow direction.

[2] Use the “Flat” roof R-values for roof angles between horizontal and 22 degrees.

[3] Use the 45 degree roof R-values for roof angles between 23 and 60 degrees.

[4]Assumes mean temperature of 90 degrees Fahrenheit, temperature difference of 10 degrees Fahrenheit, surfac

[5] Use these R-values for air spaces greater than or equal to 3.5 inches, such as attics.

Any time a typical wood-frame assembly is used, the U-factors listed in Table B-2 (see Appendix B) can be used (a portion of Table B-2 is included as Table 3-1). Table B-2 provides a wide range of typical wood-framed assemblies.

To use Table B-2, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, determine the R-value of the layer of insulated sheathing (such as rigid foam insulation board) attached to the assembly and select the row of the table showing the U-factor of the assembly. Use the “zero” R-value if there is no insulated sheathing. Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate. These default U-factors must be used for compliance purposes, unless calculations are submitted for each assembly.

Likewise, if the assembly is not included in the table, or if the assembly is a framed floor, ceiling, or soffit, the U-factor must be calculated using the parallel path method, in which case the applicant must submit calculations using form ENV-3 (see Section 3.3.4 thru 3.3.5).

Table 3-2 - Wood Framed Assembly U-factors (excerpt from Table B-2, Appendix B)

Framing Type and Spacing	Framing / Cavity R-value	Insulating Sheathing R-value	Wood Wall U-factor
Wood 2x4 @ 16 in. o.c.	11	5	0.064
		7	0.056
		8.7	0.051
	13	0	0.088
		4	0.063
		5	0.059
		7	0.052
		8.7	0.048
	15	0	0.081

Parallel Path Method. Wood framed assembly U-factors are calculated using the parallel path method (see ENV-3 Wood Framed Assembly). This method takes account of the fact that heat flows at a different rate through the solid wood framing portion of the surface than through the insulated cavity portion. The U-factor developed by the method is essentially an area-weighted average of the U-factors of the frame and cavity areas.

The parallel path method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). For compliance purposes, the parallel path method calculation is done for each wood-framed assembly using the ENV-3 form. Refer to Section 3.3.6 for a step-by-step explanation of this calculation and the form.

Because the parallel path method weights the U-factors of the framing and the cavity areas, a key number in the calculation is the *framing percentage.* This number describes the percentage of the surface area that is occupied by framing; the rest is occupied by cavity and insulation. In order to simplify the calculation and to avoid confusion, the *Energy Commission* has adopted common framing percentages, found below in Table 3-1.

Table 3-1 - Wood Framing Percentage

Assembly Type	*Framing Spacing*	*Framing Percentage*
Walls	16" o.c.	15%
	24" o.c.	12%
Floors	16" o.c.	10%
	24" o.c.	7%
Roofs	16" o.c.	10%
	24" o.c.	7%

Source: 1993 ASHRAE Handbook of Fundamentals, Chapter 22

E. Metal Frame U-factors (§141(c)4.C)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.* Metal framing, typically using steel studs, rafters or joists made of rolled shapes of light gauge steel, is common in non-combustible construction. The framing techniques are similar to those for wood framing; small dimension structural members are typically placed on 16 inch or 24 inch centers, and the cavities between the framing members are filled with insulation. This method does not apply when the framing spacing is 32 inches or more.

Metal-framed assemblies have greater heat transfer than wood-framed assemblies, of similar construction. This is because the steel material is an effective heat conductor. Heat flows rapidly through the framing members, bypassing the cavity insulation. The net result is substantial reduction in the effectiveness of the insulation.

To account for this effect, the zone method is used for determining the U-factor of a metal-framed assembly instead of the parallel path method. This method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). A hand calculation using the zone method is elaborate, and is not recommended for use without training.

Other alternatives to performing zone method calculations include the use of ENV-3 for Metal Framed Assemblies, default table (Table 3-2), and a computer program were developed by the *Energy Commission* to determine the U-factors of construction assemblies, including those with metal framing (see Appendix B).

Table 3-2 is an excerpt from Table B-2, the Wall Assembly U-factor Table found in Appendix B, which provides U-factors for a wide range of typical metal-framed wall assemblies. They were calculated using the zone method. These values may be used for compliance purposes, unless the applicant submits calculations for each assembly separately (using form ENV-3 Metal Frame; see Section 3.3.4). Interpolating or extrapolating values in this table is prohibited.

To use this table, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, use the R-value of the layer of insulated sheathing attached to the assembly and select the row of the table showing the U-factor of the assembly. Use “zero” R-value if there is no insulated sheathing.

Table 3-2 - Metal Framed Assembly U-factors (excerpt from Table B-2)

Framing Type And Spacing	Framed Wall Assembly U-Values		
2x4 @ 16" o.c.	Framing Cavity R-Factor	Insulated Sheathing R-Factor	Metal Wall U-Factor
	R-11	0.0	0.202
		4.0	0.112
		5.0	0.101
		7.0	0.084
		8.7	0.073

Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate.

If the value in Table B-2 is not used, or if the assembly is a metal-framed floor, ceiling or soffit, the U-factor may be calculated using the metal framing factors found in Table 3-3 (see Appendix B, Table B-3). Using the ENV-3 Metal Framed Assembly form described more fully in Section 3.3.4, multiply the values in this table by the sum of R-values of all layers including air films, excluding any insulated sheathing. Add the insulated sheathing R-value, if any, to obtain the total assembly R-value. Using this value, calculate the U-factor.

Table 3-3 - Metal Framing Factors

Metal Framing Factors*			
Stud Spacing	Stud Depth	Insulation R-Value	Framing Factor
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308

R-value calculation for Exterior Wall Assemblies with Metal Studs, July 19, 1990, Staff Draft Docket 90-CON-1.

*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.

F. Masonry U-factors (§141(c)4.E)

Masonry wall assemblies are typically built using concrete masonry units (block), or with various clay products (brick or tile). They also include solid masonry or concrete assemblies, such as tilt-up concrete walls. The heat flow across these walls can be complex because of the voids in the wall, the solid material bridges through the wall, and the reinforcing and grouting of some of the voids for structural reasons.

The recommended procedure for determining masonry wall U-factors are to use the tables of values provided in this *Manual* in Tables B-4 through B-6 (see Appendix B). Alternatively, it is permissible to use either the method of transverse isothermal planes described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22, or the method described in *Energy Calculations and Data*, published by the Concrete Masonry Association of California and Nevada, 1986.

A simplified version of the latter method was used to develop Table B-4, excerpted in Table 3-4 . This table lists various typical hollow unit masonry units by nominal wall thickness (12", 10", etc.), and by material type. For example, NW CMU refers to normal weight concrete masonry units (concrete blocks). The table also provides for the three typical core treatments: solid grout and two types of partially grouted core treatments. The ungrouted cells in partially grouted walls are either empty or filled with perlite insulation. The table gives the U-factor for the wall, including interior and exterior air films. It also provides the total R-value and the heat capacity (HC) (see Section 3.1.2G for more on heat capacity). The use of these numbers in determining the U-factor of complex masonry assemblies is explained in Section 3.3.5 (ENV-3: Proposed Masonry Wall Assembly).

Table 3-4 - Properties of Hollow Unit Masonry Walls (excerpt from Table B-4)

Type			Core Treatment		
			Solid	Partly Grouted with Ungrouted Cells	
			Grout	Empty	Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rw	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rw	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rw	1.8	2.0	2.8
		HC	24.8	16.5	16.5

Table B-5 in Appendix B is used to find the values for solid masonry assemblies not made up of hollow masonry units (e.g. poured concrete), and is excerpted in Table 3-5.

Table 3-5 Properties of Solid Unit Masonry and Solid Concrete Walls (excerpt from Table B-5)

Type		Layer Thickness, inches			
		3	4	5	6
LW CMU	U	na	0.71	0.64	na
	Rw	na	1.4	1.6	na
	HC	na	7.00	8.75	na
MW CMU	U	na	0.76	0.70	na
	Rw	na	1.3	1.4	na
	HC	na	7.67	9.58	na
NW CMU	U	0.89	0.82	0.76	na
	Rw	1.1	1.2	1.3	na
	HC	6.25	8.33	10.42	na
Clay Brick	U	0.80	0.72	0.66	na
	Rw	1.3	1.4	1.5	na
	HC	6.30	8.40	10.43	na
Concrete	U	0.96	0.91	0.86	0.82
	Rw	1.0	1.1	1.2	1.2
	HC	7.20	9.60	12.00	14.40

G. Heat Capacity

Heat Capacity (HC) of an assembly is the amount of heat necessary to uniformly raise the temperature of the assembly one degree F. It is calculated as the sum of the average thickness times the density times the specific heat for each component, and is expressed in Btu per square foot per degree F. Heat capacity is a measure of the thermal mass of an assembly. It is used to determine the prescriptive envelope requirements for walls and floors.

Table 3-6 - Effective R-Values for Interior Insulation Layers on Structural Mass Walls (excerpt from Table B-6)

Type		Furring space R-value without framing effects										
Actual Thickness	Frame	0	1	2	3	4	5	6	7	8	9	10
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10
0.5”	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na
0.75”	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na
1.0”	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na

For a single layer, homogeneous wall or floor, such as poured concrete walls with no applied finish materials, heat capacity can be calculated by multiplying the weight of the wall (pounds per square foot) times the specific heat. For instance, a 6 inch concrete wall (specific heat = 0.20 Btu/lb-°F) with a weight of 70 pounds per square foot would have an HC of 70 x 0.20 or 14 Btu/ft^2-°F. To calculate the wall weight from the density (pounds per cubic foot), multiply the density by the wall thickness (inches) and then divide by 12 (inches), which gives the wall weight in pounds per square foot.

For assemblies made up of many layers, the HC may be calculated separately for each layer and summed. The Proposed Construction Assembly, form ENV-3, includes a procedure for calculating HC in simple layered assemblies (see Section 3.3.6)

Table 3-7 lists the thermal properties of typical, thermally massive construction materials. See Appendix B, Table B-1, for a more thorough listing of the thermal characteristics of materials.

The HC of unit masonry walls, such as those made of concrete block or brick, are too complicated to calculate by this method. Appendix B, Materials Reference includes Tables B-4 and B-5 with HCs calculated for a large variety of masonry wall assemblies. See Section 3.1.2F for an introduction to these tables.

Table 3-7 - Thermal Mass Properties

Matter	Conductivity (Btu/hr-ft-oF)	Density (Lbs/cf)	Specific Heat (Btu/b-oF)
Adobe	0.33	120	0.20
Heavy Concrete	0.98	140	0.20
Lightweight Concrete	0.36	85	0.20
Gypsum	0.09	50	0.26
Masonry Veneer	6.62	127	0.20
Masonry Infill	0.44	120	0.20
Concrete Masonry Unit	0.59	105	0.20
Grouted Concrete Masonry Unit	1.00	134	0.20
Stucco	0.47	105	0.20
Tile in Mortar	0.67	120	0.20
Solid Wood (fir)	0.07	32	0.33
ASHRAE Handbook of Fundamentals, Table 4, Chapter 22			

H. Cool Roofs (§118, §10-113)

Cool Roof *is a roofing material with high solar reflectance and high emittance that reduces heat gain through the roof.* The term “cool roof” refers to the outer layer or exterior surface of the roof. As the term implies, the temperature of a cool roof is lower on hot sunny days than a conventional roof, reducing cooling loads and the energy required to provide air conditioning.

The reflectance criterion is obvious: dark surfaces absorb sunlight and become hot and light colored surfaces reflect sunlight and stay cooler. However, the emittance criterion is also important. Emittance relates to the ability of heat to escape from a hot surface. Surfaces with a low emittance (usually shiny metallic surfaces) trap heat in the building structure, while surfaces with a high emittance allow it to escape through radiation to the cool night sky.

There are several ways to achieve the light color and high emittance required to qualify as a cool roof. One of the best methods is to use a single ply roofing membrane with the surface properties an integral part of the material. Another way to achieve a cool roof is to apply a coating to the surface of a conventional roof membrane, such as modified bitumen or a mineral top sheet. There are a number of qualifying liquid products, including elastomeric coatings and white acrylic coatings. Coatings must be applied with a minimum thickness of 20 mils across the entire surface and meet minimum standards for durability.

There are no mandatory requirements to install cool roofs, but credits are offered through the overall envelope approach and the whole building performance method. To qualify for the cool roof credits, the exterior roof surface must have an initial reflectance greater than 0.70 (0.40 for concrete or clay tile) and an emittance of 0.75 or greater.

Before January 1, 2003, the eligibility criteria may be verified through manufacturer’s published performance data. After January 1, 2003, qualifying roofing materials must be certified and labeled by the Cool Roof Rating Council (CRRC). The certification and labeling requirements for cool roofs are specified in §10-113. The following text from the standard describes the test methods and criteria for the various classes of cool roofs.

Concrete tile (as defined in ASTM C55-99) and clay tile (as defined in ASTM C1167-96) roofing products shall have a minimum initial total solar reflectance of 0.40 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

All other roofing products shall have a minimum initial total solar reflectance of 0.70 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

Liquid applied roofing products shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements of ASTM D6083-97 when tested in accordance with ASTM D6083-97 for the following key properties: initial tensile strength, initial elongation, elongation after 1000 hours, accelerated weathering, permeance, and accelerated weathering.

Table 3-8 - Cool Roof Performance Criteria

Required Criteria	Concrete Tile	All Other Cool Roofs
Emittance	0.4	0.7
Reflectance	0.75	0.75
Material thickness	Not Applicable	20 mils for liquid applied. Not applicable for other roofing materials
Labeling		
Before 1/1/2003	Through manufacturer’s Published performance data.	Through manufacturer’s Published performance data.
After 1/1/2003	Certified and labeled by the Cool Roof Rating Council	Certified and labeled by the Cool Roof Rating Council
Compliance Credit Method	Performance and Overall Envelope	Performance and Overall Envelope

I. Fenestration U-factors (§141(c)4.D)

The U-factor for a fenestration product describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-factor includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions (there also may be spacers, sealants and other elements that affect heat conduction). For skylights mounted on a curb, the total heat flow considered in determining the U-factor includes losses through the curb, as well as the frame, glazing and other components. For projecting windows (greenhouse windows), the total heat flow includes the side panels, base and roof of the projecting window assembly. However, the area used to determine the U-factor for skylights and projecting windows is the rough framed opening. Using the rough framed opening eases the process of making load calculations and verifying compliance since the rough framed opening is easier to calculate than the actual surface area of the projecting window or skylight.

The Definitions (§101(b)) section of this chapter lists many of the terms and product characteristics that relate to fenestration U-factors. In particular see definitions for window, skylight, window area, skylight area, site-assembled fenestration, site-built fenestration and field-fabricated fenestration.

Table 3-9 shows acceptable procedures for determining fenestration U-factors for four classes of fenestration: manufactured windows, skylights, site-built fenestration and field-fabricated fenestration.

Table 3-9 - Acceptable Methods for Determining U-factors

	Fenestration Class			
			Site-Assembled	
U-factor Determination Method	Manufactured Windows	Skylights	Site-Built Fenestration	Field-Fabricated Fenestration
NFRC 100 (1997)	✓	✓		
NFRC 100-SB			✓	✓
Default U-factors from Table 3-10 (same as *Standard* Table 1-D)	✓		✓	✓
Default U-factors from Appendix B, Table B-14 same as ACM Appendix I Table I-1		✓(Note 1)	✓ (Note 2)	(Note 2)

Note 1: The default U-factors from Appendix B (Table B-14) may also be used for site-assembled horizontal glazing.

Note 2: The default U-factors from Appendix B (Table B-14) may only be used for site-assembled fenestration in buildings having less than 100,000 ft² of floor area or less than 10,000 ft² of site-assembled vertical fenestration area.

The preferred methods for determining fenestration U-factor are those in NFRC 100 (1997) for manufactured windows and NFRC 100-SB for site-built fenestration. These methods may be used for all classes of fenestration, although typically they are not practical for field-fabricated fenestration. For manufactured windows, the default U-factors in Table 3-10 below (*Standard* Table 1-D) must be used if NFRC determined U-factors are not available. This table can also be used for site-assembled fenestration (see Table above). These U-factors represent the high side of the range of possible values, thereby encouraging designers to obtain ratings through NFRC procedures, when they are available.

NFRC U-factors are less likely to be available for skylights than they are for windows, where limited test data can be extended through calculations. Typically, acrylic skylights must be individually tested. When NFRC data is not available, two other SHGC methods are available. One method is to use values from Table 3-12 (*Standard* Table 1-E from

§116). The values are on the high sided and do not account for special coatings and other technologies that may be part of a proposed fenestration product. The default U-factors for site-built fenestration in buildings less than 100,000 square feet of conditioned floor area or with less than 10,000 square feet of vertical site built glazing, are also listed in Appendix B, Table B-14.

The recommended method for determining the U-factor of site-built fenestration systems (curtain walls and storefront systems) is to use the NFRC 100-SB (site-built) procedure. This requires that a sample of the curtain wall assembly be assembled and tested in an NFRC approved laboratory. The NFRC procedure is optional for a building that has less than 100,000 ft^2 of conditioned floor area or has less than 10,000 ft^2 of site-built vertical fenestration area. If the building has less than 100,000 ft^2 of floor area or has less than 10,000 ft^2 of site-assembled vertical glazing area, then U-factors used for compliance for site-assembled products may instead be selected from Table B-14 of Appendix B of this *Manual* or Table 3-10.

Note: Manufactured fenestration in buildings under 100,000 ft^2 must still either be rated and labeled in accordance with NFRC procedures or labeled using Table 3-10 (§116, *Standard* Table 1-D) values.

For buildings larger than 100,000 ft^2 of floor area and with 10,000 ft^2 of site-built vertical fenestration area, there are two compliance choices with regard to U-factor and labeling of site-built fenestration.

- Go through the NFRC process and get a label certificate. This is the option described in §10-111(a)1C.
- Use the default tables from Table 3-10 (or §116, *Standard* Table 1-D). This is option §10-111(a)1A. This option results in very conservative U-factors.

Field-fabricated fenestration is site-assembled fenestration that does not qualify as site-built fenestration. It includes windows where wood frames are constructed from raw materials at the building site, salvaged windows and other similar products. For this class of fenestration product, U-factors may be taken from Table 3-10 below, from Appendix B, Table B-14, or by using NFRC 100-SB to determine a specific value for the field fabricated product.

Table 3-10 - Default Fenestration Product U-factors

Frame Type [Note 1]	Product Type	Single Pane U-Factor	Double Pane U-factor [Note 2]
Metal	Operable	1.28	0.87
	Fixed	1.19	0.72
	Greenhouse/Garden Window	2.26	1.40
	Doors	1.25	0.85
	Skylight	1.72	0.94
Metal, Thermal Break	Operable	n. a.	0.71
	Fixed	n. a.	0.60
	Greenhouse/Garden Window	n. a.	1.12
	Doors	n. a.	0.64
	Skylight	n. a.	0.80
Non-Metal	Operable	0.99	0.60
	Fixed	1.04	0.57
	Doors	0.99	0.55
	Greenhouse/Garden Window	1.94	1.06
	Skylight	1.47	0.68

Note 1: Metal includes any field-fabricated product with metal cladding. Non-metal framed manufactured fenestration products with metal cladding must add 0.04 to the listed u-factor. Non-metal frame types can include metal fasteners, hardware, and door thresholds. Thermal break product design characteristics are:

a. The material used as the thermal break must have a thermal conductivity ≤ 3.6 Btu-in./hr-ft²-°F,

b. The thermal break must produce a gap of ≥ 0.210 in.,

c. All metal members of the fenestration product exposed to interior and exterior air must incorporate a thermal break meeting the criteria in (a) and (b) above. In addition, the fenestration product must be clearly labeled by the manufacturer that it qualifies as a thermally broken product in accordance with §116.

Note 2: For all dual glazed fenestration products, adjust the listed U-factors as follows:

a. Subtract 0.05 for spacers of 7/16” or wider.

b. Subtract 0.05 for products certified by the manufacturer as low-E glazing.

c. Add 0.05 for products with dividers between panes if spacer is less than 7/16” wide.

d. Add 0.05 to any product with true divided lite (dividers through the panes).

J. Solar Heat Gain Coefficient (§141(c)5)

The solar heat gain coefficient (SHGC) is a measure of the quantity of solar heat entering a window or skylight; the lower the SHGC, the lower the amount of solar heat gains. A low SHGC reduces solar heat gains, thereby reducing the amount of air conditioning energy needed to maintain comfort in the building. A low SHGC may also increase the amount of heat needed to maintain comfort in the winter. The technical definition of SHGC is the ratio of solar energy entering the window (or fenestration product) to the amount that is incident on the outside of the window. As with the U-factor, frame type as well as the type of glazing affects SHGC.

There are four acceptable methods for determining SHGC for use with the *Standards* (see Table 3-11). The preferred methods are to use one of the two NFRC procedures: NFRC 200 for manufactured fenestration and skylights or NFRC 100-SB for site-built fenestration including skylights. NFRC 100-SB is a method that is available for site-built fenestration products where the glazing is in only one plane.

The third method is to use the SHGC Default Table 3-12, which is the same as Table 1-E in the Standards. These values are on the high side and do not account for special coatings and other technologies that may be part of a proposed fenestration product.

The fourth method is to use the Alternative Calculation Method for SHGC Compliance in Appendix B, Table B-12. This method allows, under limited conditions, the use of two different equations, one for site-assembled fenestration and the other for manufactured fenestration. Each equation calculates an overall SHGC for the fenestration ($SHGC_{fen}$) assuming a default framing factor and using the center-of-glass SHGC value ($SHGC_c$) for the glazing from the manufacturer's literature. The equation for site-assembled fenestration can only be used for site-built or field-fabricated fenestration for buildings that are less than 100,000 square feet of conditioned floor area or have less than 10,000 square feet of site-assembled vertical fenestration.

Note: The method outlined in Appendix B (Table B-12) to determine the SHGC for site-assembled fenestration products uses an equation that adapts data available for center-of-glass. The Equation *$SHGC_{fen} = 0.11 + 0.81 \times SHGCc$* cannot **be used for** site-assembled vertical glazing in buildings with (a) 100,000 ft^2 or more of conditioned floor area and (b) 10,000 ft^2 or more of vertical fenestration area **and after October 1, 2002 cannot be used for manufactured products regardless of the size of the building**. $SHGC_C$ data is commonly available from glass manufacturers and glazing fabricators. The data is provided in product catalogs and on their websites. Manufacturer's data for glazing materials should be **determined in a manner** consistent with NFRC 200.

Buildings that are greater than 100,000 square feet of conditioned floor area or have more than 10,000 square feet of site-assembled vertical fenestration cannot use the site-assembled equation. The equation for manufactured fenestration can only be used for manufactured fenestration in buildings for which the building permit is applied for prior to October 1, 2002. After October 1, 2002 the manufactured fenestration equation can no longer be used.

Table 3-11 - Methods for Determining SHGC

	Fenestration Class			
SHGC Determination Method	Manufactured Windows	Skylights	Site-Assembled	
			Site-Built Fenestration	Field-Fabricated Fenestration
NFRC 200 (1995)	✓	✓		
NFRC 100-SB			✓	
Default SHGC values from Table 3-12 (same as *Standard* Table 1-E)	✓	✓	✓	✓
SHGC alternative procedure from Appendix B, Table B-12 (see equations from Table B-12 below)				✓
$SHGC_{fen} = 0.08 + 0.86 \times SHGCc$		✓	✓(Note 1)	
Prior to October 1, 2002, $SHGC_{fen} = 0.11 + 0.81 \times SHGCc$	✓ (Note 2)			✓(Note 1)
Note 1: The SHGC procedure defined in Appendix B of this *Manual (Table B-12) may* only be used for site-assembled fenestration in buildings that are less than 100,000 ft^2 of floor area or have less than 10,000 ft^2 of site-assembled vertical fenestration area.				
Note 2: For permits submitted prior to October 1, 2002, manufactured fenestration products that do not have SHGC values determined using NFRC 200 may calculate the SHGC using the equation shown in the first column of this table, where $SHGC_c$ is the SHGC for the center of glass alone, and $SHGC_{fen}$ is the SHGC for the complete fenestration product including glass and frame. Beginning October 1, 2002, manufactured fenestration products must be certified for overall SHGC in accordance with NFRC 200 procedures or use Default SHGC values from Table 3-12.				

Table 3-12 - Default Solar Heat Gain Coefficients

Frame Type	Product	Glazing	Single Pane	Double Pane
Metal	Operable	Clear	0.80	0.70
	Fixed	Clear	0.83	0.73
	Operable	Tinted	0.67	0.59
	Fixed	Tinted	0.68	0.60
Metal, Thermal Break	Operable	Clear	0.72	0.63
	Fixed	Clear	0.78	0.69
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.65	0.57
Non- Metal	Operable	Clear	0.74	0.65
	Fixed	Clear	0.76	0.67
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.63	0.55

Windows are not allowed credit for any interior shading such as draperies or blinds. Only exterior shading devices (i.e. shade screens) permanently attached to the building, or a structural component of the building, can be modeled for performance standards compliance. Manually operable shading devices cannot be modeled. Only overhangs can be credited using the Relative Solar Heat Gain procedure (see Subsection N below) for prescriptive compliance.

Visible light transmission (VLT) is a property of glazing materials that has a varying relationship to SHGC. VLT is the ratio of light that passes through the glazing material to the light that is incident on the outside of the glazing. Light is the portion of solar energy that is visible to the human eye. VLT is an important characteristic of glazing materials, because it affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low VLT have little daylighting benefit and views appear gloomy, even on bright days. The ideal glazing material would have a high VLT and a low SHGC. Such a glazing material would allow solar radiation in the visible spectrum to pass while blocking radiation in the infrared and ultraviolet spectrums. Materials that have this quality are labeled “spectrally selective” and have a VLT that is 20% or so higher than the SHGC. Higher VLT can result in energy savings in lighting systems. See Section 5.2.1.

K. Site-built Fenestration (§116, §10-111)

Manufactured fenestration products arrive at the construction site as a unit, and the manufacturer is able to assume the burden of testing and labeling. However, with site-assembled fenestration, multiple parties are responsible. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and sometimes, the method of assembly. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks, etc. A glazing manufacturer provides the glazing units, cut to size and fabricated as insulated glass (IG) units. The glazing manufacturer is responsible for tempering or heat strengthening, the tint of the glass, any special coatings, the spacers and sealants. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site and is responsible for many quality aspects. Glazed wall systems are often custom designed for buildings, making it more difficult to predetermine the performance of the system as a whole, as compared to manufactured units.

The National Fenestration Rating Council (NFRC) adopted NFRC 100-SB (Site-Built) in 2000 to address the special needs of site-built fenestration products. The NFRC procedures are recommended for all site-built fenestration systems, but are mandatory for large construction projects unless the high range default values from Table 3-10and Table 3-12 are used. Large construction projects are those that have 100,000 ft² or more of floor area and 10,000 ft² or more of site-built vertical fenestration. The requirement is intended to apply to large office buildings and other nonresidential buildings with large curtain wall systems. The cost for testing and labeling site-built glazing systems varies with the size of the project. Many of the costs are fixed, so the cost per square foot is lower in larger projects. This is the primary initially rationale for requiring NFRC testing and labeling only for larger construction projects.

One of the parties (architect, glazing contractor, extrusion manufacturer, insulated glass unit (IG) fabricator, or glass manufacturer) must take responsibility for testing and labeling of the site-built fenestration system under the NFRC 100-SB procedure. The responsible party must obtain a NFRC license and establish a relationship with a NFRC certified simulation laboratory, a NFRC certified testing laboratory and a NFRC certified independent agent (IA). For more information on the licensing process, refer to the NFRC web site at http://www.nfrc.org/.

The responsible party must work with the glazing or curtain wall supplier(s) to carry out the following steps:

- Arrange for a NFRC accredited simulation laboratory to evaluate and determine the thermal performance of each product line.
- Make an arrangement with a NFRC accredited testing laboratory to conduct a validation test on each product line.
- Forward copies of the simulation and test reports to a NFRC accredited independent agent (IA) for review.

The NFRC certified independent agent (IA) then issues an NFRC Label Certificate that is kept on file in the general contractor's construction office and posted on-site for review by the building code inspector. The NFRC Label Certificate provides the same function as the temporary label that is required for manufactured fenestration products.

It is typical for the glazing contractor to assume responsibility for the team and to coordinate the certification and labeling process. A common procedure is for the design team to include language in the contract documents that require that the general contractor be responsible; the general contractor typically assigns this responsibility to the glazing contractor. Once the glazing contractor has established a relationship with an independent agent (IA), a simulation laboratory and a testing laboratory, the process works well, and it should not delay either the design or construction process.

It is not necessary to complete the NFRC testing and labeling prior to filing the building permit application and completing the compliance documentation. However, plan examiners should verify that the fenestration performance shown in the contract documents (plans and specifications) and used in the compliance calculations is "reasonable" and achievable. This requires some judgment and knowledge on the part of the plans examiner. Generally, designers will know the type of glass that they plan to use and whether or not the frame has a thermal break or is thermally improved. This information is adequate to consult the default values in Appendix B, Table B-14. If the values used for compliance are within 5% of the values from Appendix B, Table B-14, then the values may be considered reasonable for plan check. If the compliance values are outside the 5% range, the plans examiner should request information from the designers to justify the proposed values. It may be necessary for the design team to consult with NFRC simulation laboratories to determine what technologies might be required to achieve the specified level of performance.

After the construction contract is awarded, the glazing contractor assumes responsibility for getting the simulations and tests made and for obtaining the NFRC Label Certificate. The IA issues a separate label certificate for each "product line". Each label certificate has the same information as the NFRC temporary label for manufactured products, but includes other information specific to the project such as the name of the glazing manufacturer, the extrusion contractor, the places in the building where the product line is used and other details. The label certificate remains on file in the construction office for the building inspector to view. After construction is complete, the label certificate should be filed in the building office with the as-built drawings and other operations and maintenance data. This will give building managers the information needed for repairs or replacements. Those who use Field-fabricated fenestration do not usually follow the NFRC 100-SB process and instead use default values published by the Commission. See Table 3-1and Table 3-12

Example 3-1– NFRC Testing of Site-Built Fenestration

Question

A designer is using a U-factor of 0.57 for compliance with a curtain wall system. The glazing system uses two lites of 1/4 inch glass with a low-e coating on the second surface. The air gap is 1/2 inch. A standard metal frame is proposed for the curtain wall system. Is 0.57 a reasonable U-factor for compliance and can it reasonably be achieved by the glazing contractor through the NFRC process for site-built fenestration?

Answer

The default U-factor for this glazing combination from Appendix B (Table B-14) is 0.59. The proposed factor of 0.57 is within 5% and should be considered reasonable.

L. Product Line

Product[1] – One of the components of a product line that may have different glass types, different edge of glass characteristics, true or simulated dividers within the glass, or different gas fills.

Product Line[2] – General group of fenestration products that have a similar frame and operating characteristics. Products that are constructed from the same frame material and designs, but differ only in operating characteristics (e.g. a vertical slider and horizontal slider of the same construction) may be in the same product line. Minor changes to hardware to accommodate higher/lower loads and stresses do not necessarily constitute a different product line.

A product line[3] is a given series of fenestration products with the same operator type that differ only in:

1. Size
2. Center-of-glass and edge-of-glass characteristics such as glazing types, glazing coatings, gas-fills, gap widths, use of dividers, use of spacers;
3. Opening/non opening configurations, e.g., XO vs XOX
   - Where an "X "denotes an operating panel/sash
   - An "O" denotes a fixed or non-operating panel/sash

- Combinations of X's and O's denote the appropriate combinations of operating and non-operating panels

4. Minor changes to accommodate smaller/larger glazing unit widths;
5. Minor changes to operating hardware to accommodate higher/lower loads and stresses (including the use of reinforcing in vinyl framed fenestration products);
6. Frame or sash changes where one component is replaced by another component of the same physical shape with a thermal conductivity that does not differ by more than a factor of 10; and

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[1] NFRC Certified Products Directory, Ninth edition – December 1999

[2] NFRC Certified Products Directory, Ninth edition – December 1999

[3] NFRC 100 Combined: Procedures for Determining Fenestration Product U-factors – 2000 Edition

7. Interior/exterior appendage added to the main web of the frame that are not exposed after product installation, i.e., nailing fins.

A product line is thus defined by an operator type and a set of basic frame profiles. For each frame/sash element, a base profile must be defined. Frame/sash profiles which differ from these base profiles are part of the same product line as long as the differences are limited to lengthening, shortening, expanding, or deleting specific elements of the base profile (typically incorporated into the product line for different installations). Such differences in the base profile constitute different individual products within the product line. Material changes where the conductivity changes by more than a factor of 10 are not part of the same product line except for the addition of cladding materials applied to the base profile.

Multipurpose fenestration products incorporating nearly identical frame/sash base profiles can be classified and rated as one product line. The products shall be classified in separate groups by operator type within the product line.

Clad products and unclad products can be incorporated into one product line if and only if the cladding system represents a minor change to the frame/sash base profile. The clad and unclad products would be separate individual products within the product line.

Multiple assemblies sometimes referred to as combination or composite windows, including more than one operator type, (e.g., a vertical slider over an awning) and multiple assemblies of the same operator type need not be rated in combination. Each operator type may be evaluated separately.

Non-rectangular fenestration products shall be rated as though they are rectangular fenestration products. Identify all the frame cross sections of the non-rectangular fenestration product. Find or develop a product line with the same frame cross sections as the non-rectangular fenestration product, and choose the rectangular size closest to residential and nonresidential for simulation and testing. If there are no rectangular sizes available in those ranges, a non-rectangular fenestration product with the same frame cross sections, and the closest possible total area can be used for simulation or testing.

M. Fenestration Labeling (§10-111 and 116)

The Administrative Regulations (§10-111) and the *Standards* (§116) require that fenestration products have labels that list the U-factor, the solar heat gain coefficient (SHGC), and the methods used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage. The air leakage requirements are specified in §116 and limit the infiltration rate to 0.3 cfm/ft² for most products.

Each Manufactured fenestration product must have a clearly visible temporary label attached to it, which is not to be removed before inspection by the enforcement agency. For rating and labeling manufactured fenestration products, the manufacturer has two choices for U-factor and, until October 1, 2002, three choices for SHGC. First, the manufacturer can choose to have the fenestration product rated and labeled in accordance with the NFRC Rating Procedure (NFRC 100 for U-factors and NFRC 200 for SHGC). If the manufactured fenestration product is rated using the NFRC Rating Procedure, it must also be permanently labeled in accordance with NFRC procedures. Second, if the manufacturer can choose to use Default values from Table 3-10 for U-factors and Table 3-12 for SHGC. If Default values are used, the manufacturer must attach a temporary label meeting specific requirements (permanent labels are not required). Figure 3-7 shows a sample Default temporary label. Although there is no exact format for the Default temporary label, it must be clearly visible, large enough for the building department field inspectors to easily read it, and include all information required by the regulations. The suggested label size is 4 inches X 4 inches. The label shall have the words “CEC Default U-factor” followed by the correct value for that fenestration product from Table 3-10 and the words “CEC Default SHGC” followed by the correct value from Table 3-12. The U-factor and SHGC Default values should be large enough to be visible from 4 feet. If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criterion, upon which the default value is based, is met. This can be done by placing the term "Meets Thermal-Break Default Criteria" on the temporary label. Note 2 of Table 3-10, the Default U-factor table, provide for positive or negative adjustments to the U-factors in the table for specific fenestration products. For example, products with low-E glazing or air gaps between panes greater than 7/16 inch are adjusted to lower U-factors and products with true divided lites or metal cladding are adjusted to raise U-factors. These adjustments must be included in the U-factor shown on the temporary label. The special features that cause these adjustments should be identified on the label. The manufacturer may also include the VLT factor from manufacturer's data. This factor is important to determine whether daylit area credit may be taken in conjunction with daylighting controls.

For site-built fenestration systems, a label certificate takes the place of both the temporary and permanent label.

Figure 3-7 – Sample Default Temporary Label

CEC Default Label	**XYZ MANUFACTURING Co.**
Key Features:	**Double Pane** **Operable** **Metal, Thermal Break** **Air space 7/16" or greater** **Tinted**
CEC Default U-factor 0.66	**CEC Default SHGC 0.53**
Manufacturer certifies that this Fenestration Product meets the air infiltration requirements of §116 (a) 1 and the thermal-break default criteria of §116 (a) 2, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.	

For site-assembled fenestration products, a label certificate can take the place of the temporary label (permanent labels are not required). For site-built fenestration, NFRC Label Certificates result from ratings through the NFRC 100-SB procedures. For site-assembled fenestration products, which are not rated through the 100-SB procedures, a Default Label Certificate can be provided by the person (e.g., architect, glazing contractor, extrusion manufacturer, IG fabricator or glass manufacturer) taking responsibility for fenestration compliance. Figure 3-8 is a sample CEC Default Label Certificate when using default values from Table 3-10 and Table 3-12, and Figure 3-9 is a sample of the CEC Alternate Default Label Certificate when using default values from Appendix B, Tables B-12 and B-14. A separate Default Label Certificate should be completed for each product line that results in a different U-factor and SHGC. The Default Label Certificate should state the amount of this product line throughout the project, the locations in the project where the product line is installed, and the pages in the drawings and fenestration schedule, which show this product line. The Default Label

Certificate should clearly identify the appropriate table or equation that is used to determine the Default U-factor and SHGC, and the frame type, product type and glazing type that corresponds to the appropriate table and if applicable the center of glass $SHGC_c$ used in calculating the $SHGC_{fen}$. Manufacturer's documentation of these product characteristics must also be attached to the plans. The Default Label Certificate also should contain the words "Meets Thermal-Break Default Criteria" if the product claims the default U-factor for a thermal-break product. The Default Label Certificate also should identify any special features that cause adjustments to raise or lower the default U-factor as specified by the Default U-factor table. The Default Label Certificate may also include the VLT factor to determine whether daylit area credit may be taken in conjunction with daylighting controls. The person taking responsibility for fenestration compliance for the project can choose to attach Default Temporary Labels to each fenestration product as described in the previous paragraph instead of providing Default Label Certificates for each product line. A CEC Alternate Default Label Certificate is acceptable documentation of the information specified in Appendix B, Tables B-12 and B-14 for Field-fabricated fenestration.

Example 3-2– NFRC Testing of Site-Built Fenestration

Question

A 150,000 ft² "big box" retail store has 2,000 ft² of site-built vertical fenestration located at the entrance. The fenestration system consists of two lights of clear 1/4 inch mm glass separated by a 1/2 inch air gap. An aluminum storefront framing system is used, without a thermal break. What are the acceptable methods for determining the fenestration U-factor and SHGC? What are the labeling requirements?

Answer

The site-built fenestration does not have to be rated through the NFRC 100-SB procedures since the total area of vertical site-assembled fenestration is less then 10,000 ft². Also, permanent labels are not required.

The U-factor may be selected from Table B-14 in Appendix B. This table is also contained in Appendix I of the ACM Approval Manual. The U-factor for the specified product is 0.73, which is taken from the first column of the table for double glass with a ½ in. air gap (roughly 12 mm).

The SHGC for the center of the glass is known from manufacturers data and is 0.70. The SHGC for the fenestration product (including the frame) is 0.68 as determined using the following equation:

$$\begin{aligned} SHGCfen &= 0.08 + 0.86 \times SHGCc \\ &= 0.08 + 0.86 \times 0.70 \\ &= 0.68 \end{aligned}$$

A Default Label Certificate should be completed for this fenestration unless the responsible party chooses to attach Default Temporary Labels to each fenestration product throughout the building.

Figure 3-8 – CEC Default U-Factor and SHGC Label Certificate

U-FACTOR AND SHGCLABEL CERTIFICATE FORM

PROJECT INFORMATION	
PROJECT NAME: **RIVER CITY OFFICE**	DATE: **August 1, 2001**
PROJECT ADDRESS: **321 North 5th St. Sacramento, CA 95814**	

CEC DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE (Use only for Site-Assembled Fenestration Product Lines) Method 1 in this Default Certificate may be used for site-assembled vertical glazing installed in all non-residential buildings.	U-factors and SHGC are derived from the California Energy Commission Fenestration Default U-factors and SHGC Default Table based on data reported below. **U-factor = 0.71** **SHGC = 0.73** This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)			
Total Number of units for this product line:	**2**	Total square footage of this product line:	**480**
Elevation drawing page:	**E-3**	Fenestration (window & door) schedule page:	**E-4, E-6**
Location(s) on building: (enter appropriate orientation(s))	**South, East, West and North**	Total Fenestration Area (ft^2) on project:	**960**

❑ **Method 1 -** - **DEFAULT FENESTRATION U-FACTOR AND SHGC FROM TABLES 3-10 AND 3-12 OF THE NONRESIDENTIAL MANUAL FOR COMPLIANCE WITH THE 2001 ENERGY EFFICIENCY STANDARDS**

Frame Type	X Metal	❑ Metal Thermal Break (or Structural Glazing)			❑ Nonmetal
U-factor Table 3-10 Product Type	❑ Operable	X Fixed	❑ Greenhouse, Garden Window	❑ Door	❑ Skylight
Glazing Type	❑ Single Pane	X Double Pane	**Default U-factor =**	0.72	(If no adjustment, insert value in above gray box next to U-factor)
SHGC Table 3-12 Product Type	❑ Operable	X Fixed			
SHGC Table 3-12 Glazing Tint	X Clear	❑ Tint	**Default SHGC =**	0.73	(Insert default value in above gray box next to SHGC)

U-Factor Adjustment (See Table 3-10, Footnote 2)

X Subtract 0.05 for spacers of 7/16 inch or wider
X Subtract 0.05 for products certified by the manufacturer as low-E glazing.
❑ Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide.
❑ Add 0.05 for products with true divided lite (dividers through the panes).

U-Factor Adjustment = 0.72 – 0.05 – 0.05 = **0.71** (If applicable insert adjustment result in above gray box next to U-factor)

PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:		
Contact Person: **Joe Glassguy**		
Company name and address: **453 Venice Way**		
Phone: **916-555-5555**	Fax:	Signature: *Joe Glassguy*

Figure 3-9 – CEC Alternate Default U-Factor and SHGC Label Certificate

ALTERNATIVE DEFAULT U-FACTOR and SHGC LABEL CERTIFICATE

PROJECT INFORMATION	
PROJECT NAME: **RIVER CITY OFFICE**	DATE: **August 1, 2001**
PROJECT ADDRESS: **3212 North 5th St. Sacramento, CA 95814**	

CEC ALTERNATIVE DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE (Use only for Site-Assembled Fenestration Product Lines)	U-factors and SHGC are derived from the California Energy Commission Fenestration Alternative Default U-factors and SHGC Equations based on data reported below. **U-factor = 0.66** **SHGC = 0.42**
Method 2 Alternative Default Certificate shall not be used for site-assembled vertical glazing installed in buildings with 100,000 square feet or more of conditioned floor area and 10,000 square feet or more of vertical glazing.	This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)

Total Number of units for this product line:	**2**	Total square footage of this product line:	**480**
Elevation drawing page:	**E-3**	Fenestration (window & door) schedule page:	**E-4, E-6**
Location(s) on building: (Enter appropriate orientation(s))	**South, East, West and North**	Total Fenestration Area (ft^2) on project:	**960**

☐ **Method 2 - - DEFAULT FENESTRATION U-FACTOR AND SHGC FROM APPENDIX B, TABLE B-14 AND MANUFACTURER'S DOCUMENTATION**

Product Type	X Glazed Wall Systems	☐ Skylight with Curb	☐ Skylight without Curb			
Frame Type	X Aluminum	☐ Aluminum Metal Thermal Break	☐ Wood/Vinyl	☐ Reinforced Vinyl/ Aluminum Clad Wood	☐ Structural Glazing	
Glazing Type, Glazing Thickness	☐ Single ⅛" Glass	☐ Single ⅛" Acrylic/polycarb	☐ Single ¼" Acrylic/polycarb	X Double-Glass	☐ Triple Glazing	☐ Quadruple Glazing
Coating Emissivity	☐ 0.05	☐ 0.10	☐ 0.20	X 0.40	☐ 0.60	
Coated Surfaces	X 2 or 3	☐ 2, 3, 4, or 5	☐ 2 or 3 and 4 or 5			
Glazing Spacing	☐ 1/4" Airspace	X 1/2" Airspace				
Gas Fill between Panes	X Air	☐ Argon	☐ Krypton			

CEC ALTERNATIVE DEFAULT FENESTRATION U-FACTOR =	**0.66**	From Assembly U-Factors - Appendix B, Table B-14 (Insert value in above gray box next to U-factor)

DEFAULT SOLAR HEAT GAIN COEFFICIENT

SHGC for Center of Glass	**SHGCc =**	**0.40**	From Manufacturer's Documentation (Insert value "SHGCc" in equation below)
Calculate SHGC Fenestration Equation from Appendix B, Table B-12 (Site-Assembled)	$SHGC_{fen} = 0.08 + (0.86 \times SHGCc) =$	**0.42**	(Insert result value in above gray box next to SHGC)

ATTACHED MANUFACTURED DOCUMENTATION

Manufacturer's documentation must be attached showing the Product Type, Frame Type, Glazing Type, and SHGCc information needed to determine the Default U-factor and SHGC from the Applicable Table or equation.

PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:

Contact Person:

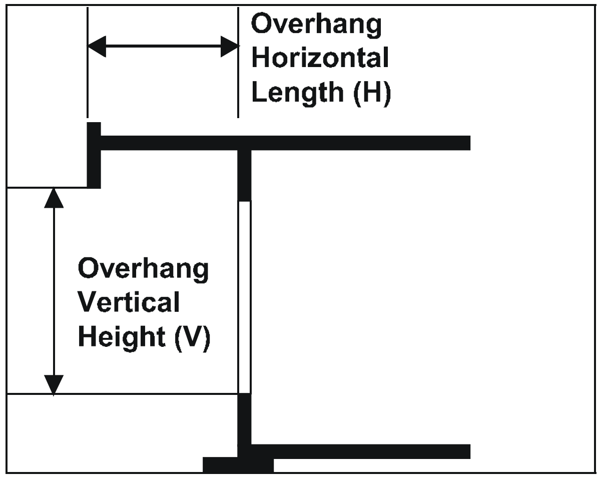
Company name and address:

Phone:	Fax:	Signature:

N. Relative Solar Heat Gain §143(a)5.C)

This value is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by an overhang factor. If an overhang does not exist, then the overhang factor is 1.0.

Figure 3-10– Overhang Dimensions



Overhang factor may either be calculated (see Equation 3-1) or may be taken from Table 3-13. The factor depends upon the ratio of the overhang horizontal length (H), and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-10. An overhang factor may be used *if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection (§143(a)5.C.ii).* The overhang projection is equal to the overhang length (H) as shown in Figure 3-10. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough to each side of the window.

Equation 3-1– Relative Solar Heat Gain

$$RSHG = SHGCwin \times OHF$$

Where

RSHG = Relative solar heat gain.

$SHGC_{win}$ = Solar heat gain coefficient of the window.

OHF = Overhang factor = $[1 + aH/V + b(H/V)^2]$

Where

H = Horizontal projection of the overhang from the surface of the window in feet, but no greater than V.

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

a = -0.41 for North-facing windows, -1.22 for South-facing windows, and -0.92 for East- and West-facing windows.

b = 0.20 for North-facing windows, 0.66 for South-facing windows, and 0.35 for East- and West-facing windows.

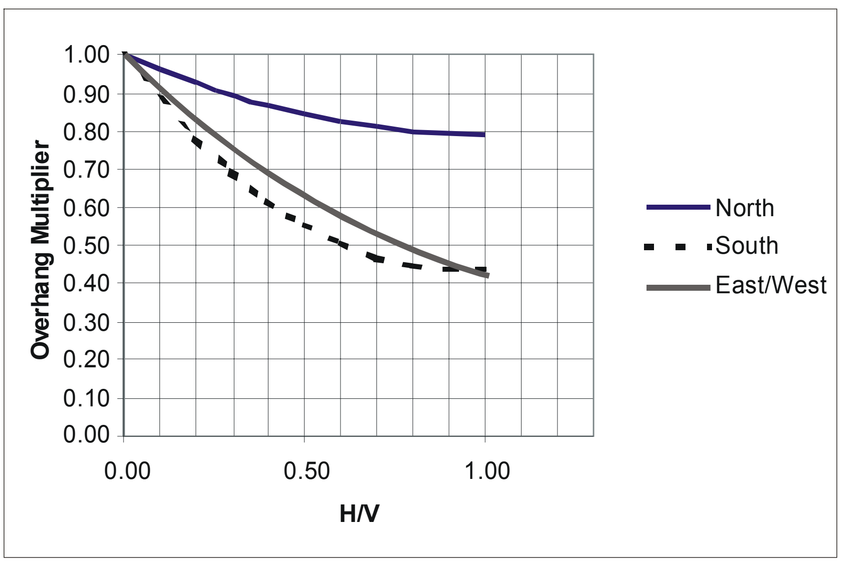
Table 3-13 - Overhang Factors

H/V	North	South	East/West
0.00	1.00	1.00	1.00
0.10	0.96	0.88	0.91
0.20	0.93	0.78	0.83
0.30	0.90	0.69	0.76
0.40	0.87	0.62	0.69
0.50	0.85	0.56	0.63
0.60	0.83	0.51	0.57
0.70	0.81	0.47	0.53
0.80	0.80	0.45	0.49
0.90	0.79	0.44	0.46
1.00	0.79	0.44	0.43

To use Table , measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cut-off point of the overhang (V). Then calculate H/V. Enter the table at that point. Move across to the column that corresponds to the orientation of the window and find the overhang factor. Note that any value of H/V greater than one has the same overhang factor (for a given orientation).

Figure 3-11 graphs the overhang factors of the various orientation as a function of H/V. It shows that overhangs have only a minor effect on the north (maximum reduction in SHGC is only about 20 percent). East, west and south overhangs can achieve reductions of 55 - 60 percent. The benefits of the overhang level off as the overhang becomes large. (Note: this graph is presented only to illustrate the benefits of overhangs. Do not use the graph to scale values of the overhang factor; use Table 3-13 or calculate the value directly from Equation 3-1.)

Figure 3-11– Graph of Overhang Factors



Example 3-3– RSHG Calculation

Question

An east-facing window has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends three feet out from the plane of the glass (H=3), and is six feet above the bottom of the glass (V=6). The overhang extends more than three feet beyond each side of the glass and the top of the window is less than two feet vertically below the overhang. What is the RSHG for this window?

Answer

First, calculate H/V. This value is 3 / 6 = 0.50. Next, find the overhang factor from Table 3-13. For east-facing windows, this value is 0.63. Finally, multiply it by the solar heat gain coefficient to obtain the RSHG: 0.63 x 0.71 = 0.45 = RSHG.

3.2 Envelope Design Procedures

3.2.1 Mandatory Measures

The mandatory measure requirements apply to new construction, additions and altered envelope components.

A. Doors, Windows and Skylights (§116)

The mandatory measures for doors, windows and skylights address the air-tightness of the units and how their U-factor and SHGC are determined. Fenestration products must be labeled with a U-factor and SHGC and the manufacturer or an independent certifying organization must certify that the product meets the air infiltration requirements of §116(a). Site-built fenestration in large projects (more than 100,000 ft² of floor area and more than 10,000 ft² of site-built vertical fenestration area) must have a label certificate issued by NFRC that is filed in the contractors project office during construction and in the building managers office after construction.

Doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-14. For field-fabricated products or an exterior door, the *Standards* require that the unit be caulked, gasketed, weather-stripped or otherwise sealed (§116(b)). Unframed glass doors and fire doors are the two exceptions to these requirements.

Where possible, it is best to decide what make and model of fenestration will be used before completing compliance documents. This enables the use of NFRC certified data to be used for compliance purposes. For site-built fenestration products, the label certificate will likely be generated by the glazing contractor after the construction project is awarded. For compliance purposes, the designer should select a U-factor and SHGC for the fenestration system that is reasonable and achievable. For U-factor, Appendix B should be used as a guide. The SHGC equations (see above) in combination with SHGC data for glazing materials should be used to determine a reasonable value for SHGC to use for compliance purposes.

Table 3-14 - Maximum Air Infiltration Rates

Class	Type	Rate
Windows (CFM/ft²) of window area	All	0.3
Residential Doors (CFM/ft²) of door area	Swinging, Sliding	0.3
All Other Doors (CFM/ft²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

B. Joints and Openings (§117)

The basic requirement of this section is that all joints and other openings in the building envelope that are potential sources of air leakage be caulked, gasketed, weather-stripped, or otherwise sealed to limit air leakage into or out of the building. This applies to penetrations for pipes and conduits, ducts, vents and other openings. It means that all gaps between wall panels, around doors Ceiling joints, lighting fixtures, plumbing openings, doors and windows, and other construction joints must be well sealed.

Ceiling joints, lighting fixtures, plumbing openings, doors and windows should all be considered as potential sources of unnecessary energy loss due to infiltration. No special construction requirements are necessary for suspended (T-bar) ceilings. Standard construction (insulation on ceiling tiles) is adequate for meeting the infiltration/exfiltration requirements.

C. Insulation Materials (§118)

The California Quality Standards for Insulating Materials, which became effective on January 1, 1982, ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Manufacturers must certify insulating materials to comply with California Quality Standards for Insulating Materials. Builders may not install the types of insulating materials listed in Table 3-15 unless the product has been certified by the manufacturer. Builders and enforcement agencies should use the Department of Consumer Affairs *Consumer Guide and Directory of Certified Insulation Material* to check compliance. (Note this is not an *Energy Commission* publication.) If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Thermal Insulation Program at (916) 574-2046.

The California Quality Standards for Insulating Materials also require that all exposed installations of faced mineral fiber and mineral aggregate insulations must use fire retardant facings that have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

Flames spread rating and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

Table 3-15 - Certified Insulating Materials

Type	***Form***
Aluminum foil	Reflective foil
Cellular glass	Board form
Cellulose fiber	Loose fill and spray applied
Mineral aggregate	Board form
Mineral fiber	Blankets, board form, loose fill
Perlite	Loose fill
Phenolic	Board form
Polystyrene	Board form, molded extruded
Polyurethane	Board form and field applied
Polyisocyanurate	Board form and field applied
Urea formaldehyde	Foam field applied
Vermiculite	Loose fill

D. Demising Walls (§118(e))

Demising walls separating conditioned space from enclosed unconditioned space must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. This requirement applies to buildings meeting compliance under the prescriptive or performance approach. This requirement assures at least some insulation in a wall where an adjoining space may remain unconditioned indefinitely.

3.2.2 Prescriptive Envelope Component Approach (§143(a))

The Envelope Component Approach is the simplified approach. Under this approach, each of the envelope assemblies (walls, roofs, floors, windows, skylights) complies individually with its requirement. If one piece of the envelope does not comply, the entire envelope does not comply. The simplicity of this approach means there can be no trade-offs between components. If one or more of the envelope components cannot meet its requirement, the alternative is to use either the Overall Envelope or the Performance Approach, either of which allows trade-offs between components.

Under the Envelope Component Approach, the requirement for each opaque (non-glazing) component takes one of two forms: R-value of its insulation or overall U-factor of the assembly. Glazing component requirements address U-factor, solar heat gain coefficient, and an upper limit on glazing area. The requirements are found in Table 3-22 and Table 3-23 with applicable excerpts in the following sections. The requirements vary by climate zone, occupancy and, in some cases, heat capacity. Compliance is demonstrated on the ENV-2, Envelope Component Method form.

A. Exterior Roofs and Ceilings (§143(a)1)

Exterior roofs or ceilings can meet the component requirements in one of two ways (see Figure 3-12) - install the required R-value of insulation (see Table 3-17), or demonstrate that the overall U-factor of the assembly meets the required U-factor (§141(c)4). If the insulation by itself meets the R- value requirement, then that component complies with this approach. If not, then the U-factor calculation allows for the overall insulating qualities of the assembly, which also acknowledges the effects of wood or metal framing. For ceilings the effects of T-bar framing and metal lighting fixtures must be included in determining the overall U-factor of an assembly.

When recessed lights are not of Type IC (rated for insulation contact), the weighted average ceiling assembly is calculated as two parallel assemblies:

1. The effective R-value of the ceiling assembly is the sum of (a) T-bar/acoustic tile (to account for the metal grids, assume 1/2 the tile's R-value); (b) ceiling insulation; and (c) two inside air film resistances (0.61 R-value per air film).

2. The effective R-value of the light fixtures is calculated as the sum of two inside air film resistances (0.61 R-value per air film). If the fixtures include plastic diffusers, the R-value of the light fixture should be calculated as two air film resistances and a 1.5 inch air space (0.77 R-value).

Note: When fixtures are IC-rated and covered by insulation, the insulation R-value alone may be used to show compliance with the prescriptive requirements or the above calculation can be modified to include the insulation R-value in the light fixture assembly.

The two parallel assemblies are then weight averaged and the overall U-factor calculated.

Note: You cannot use the EZFRAME program for T-bar/drop ceiling assemblies.

When envelope calculations are prepared before the lighting plan, the following default values (Table 3-16) may be used to determine the percentage of the ceiling assembly made up of light fixtures:

Table 3-16 - Default Light Fixture Percentages for General Commercial and Industrial Buildings

Building Type	***Percent of Ceiling as Lighting Fixture***
Work Buildings	10%
Grocery	15%
Industrial/Commercial Storage	7%
Medical Buildings	12%
Office Building	12%
Religious Worship, Auditorium, and Convention Center	16%
Restaurants	12%
Retail and Wholesale	16%
Schools	15%
Theaters	12%
All Others	7%

Figure 3-12– Roof/Ceiling Flowchart

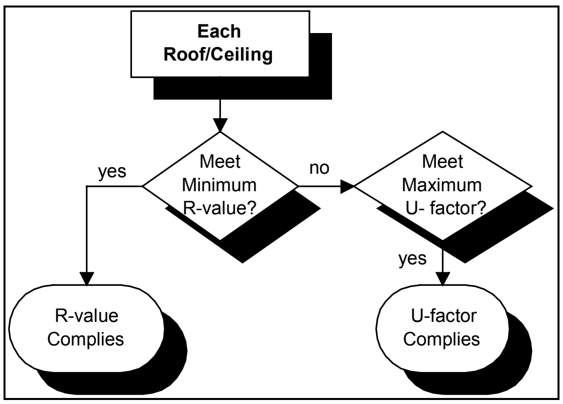


Table 3-17 - Roof/Ceiling Requirements

		Climate Zones				
Space Type	Criterion*	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	19	19	11	19	19
	U-factor	0.057	0.057	0.078	0.057	0.057
Residential High-rise	R-value	30	19	19	30	30
	U-factor	0.037	0.051	0.051	0.037	0.037

*U-factors are the actual conductance of the entire assembly. R-values refer to the nominal R-value of the insulation within the framing.

B. Exterior Walls (§143(a)2)

Exterior walls can meet the component requirements in one of two ways (see Figure 3-13) - install the required R-value of insulation (see Table), or demonstrate that the overall U-factor of the assembly meets the required U-factor (§141(c)4). If the insulation by itself meets the R-value requirement, then that component complies under this approach. If not, then the U-factor calculation allows credit for the overall insulating qualities of the assembly, which includes accounting for the effects of wood or metal framing in the assembly.

The required U-factor depends on the type of wall construction. There are five classes of wall: wood frame, metal frame, medium mass, high mass and other. The “other” category is used for any wall type that does not fit into one of the other four wall classes. The mass walls are distinguished by their heat capacity (HC); the higher the HC, the higher the wall U-factor may be (see Heat Capacity discussion in Section 3.1.2G). Medium mass walls have an HC between 7 Btu/ft^2-°F and 15 Btu/ft^2-°F. High mass walls have an HC greater than 15 Btu/ft^2-°F .

Framed wall assemblies will seldom have an HC greater than 7 Btu/ft^2-°F . Medium mass walls will have at least one fairly heavy layer, such as two coat stucco or a brick veneer, in order to have an HC higher than 7 Btu/ft^2-°F. High mass walls are generally of masonry or concrete construction.

The proposed wall U-factor must be calculated by an appropriate method (see §141(c)4). Framed assemblies must account for framing affects. Masonry assemblies must account for two dimensional heat flow. See Section 3.1.2D, E, and F for a complete discussion of the various methods and forms for determining U-factors.

Figure 3-13– Wall Flowchart

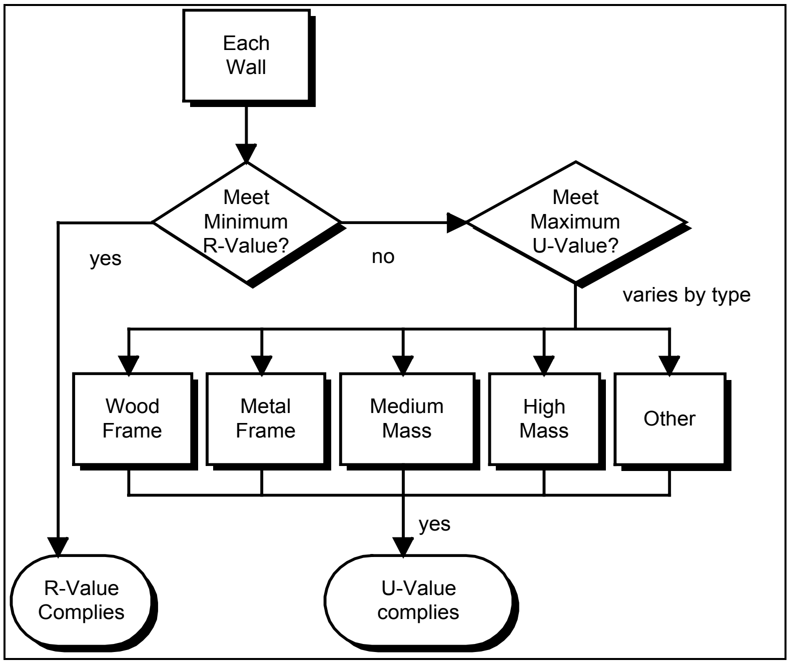


Table 3-18 - Wall Requirements

		Climate Zones				
Space Type	Criterion	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	13	11	11	13	13
	U-factor					
	Wood frame	0.084	0.092	0.092	0.084	0.084
	Metal frame	0.182	0.189	0.189	0.182	0.182
	Mass/7.0≤ HC<15.0	0.340	0.430	0.430	0.430	0.430
	Mass/15.0≤HC	0.360	0.650	0.690	0.650	0.400
	Other	0.084	0.092	0.092	0.084	0.084
Residential High-rise	R-value	19	19	11	19	19
	U-factor					
	Wood frame	0.063	0.092	0.092	0.084	0.084
	Metal frame	0.140	0.181	0.181	0.175	0.175
	Mass/7.0≤ HC<15.0	0.340	0.430	0.430	0.430	0.430
	Mass/15.0≤HC	0.360	0.650	0.690	0.650	0.400
	Other	0.063	0.092	0.092	0.084	0.084

C. Demising Walls (§143(a)3 & 5)

Demising walls, separating conditioned space from enclosed unconditioned space, must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. If it is not a framed assembly, then no insulation is required. This only applies to the opaque portion of the wall. A *demising wall* is not an *exterior wall.*

The rationale for insulating demising walls is that the space on the other side may remain unconditioned indefinitely. For example, the first tenant in a warehouse building cannot know whether the future neighbor will use the adjoining space as unheated warehouse space or as an office. This requirement assures at least some insulation in the wall.

D. Exterior Floors and Soffits (§143(a)4)

Exterior floors and soffits can meet the component requirements using two methods (see Figure 3-14) - install the required R-value of insulation (see Table 3-19), or demonstrate that the overall U-factor of the assembly meets the required U-factor (see §141(c)4). The U-factor calculation allows for calculating the overall insulating qualities of the entire assembly, which includes accounting for the effects of wood or metal framing in the assembly.

Figure 3-14– Floor/Soffit Flowchart

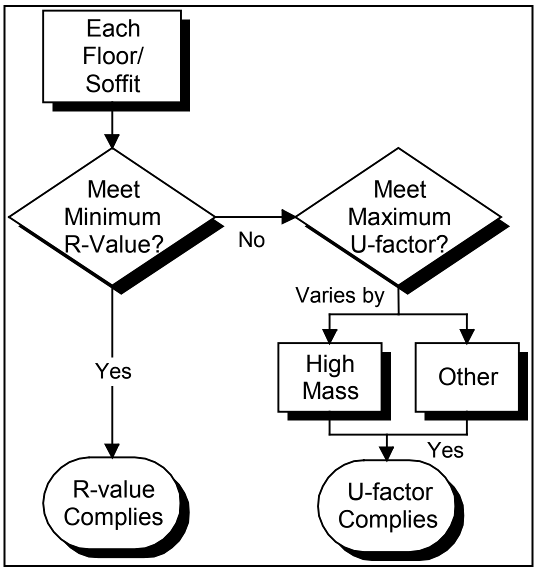


Table 3-19 - Floor/Soffit Requirements

Space Type	Criterion	Climate Zones 1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	19	11	11	11	11
	U-factor					
	Mass/7.0≤HC	0.097	0.158	0.158	0.097	0.158
	Other	0.05	0.076	0.076	0.076	0.076
Residential High-rise	R-value	19	11	11	11	11
	U-factor					
	Mass/7.0≤HC	0.097	0.158	0.158	0.097	0.158
	Other	0.05	0.076	0.076	0.076	0.076
	Raised concrete R-value	8	*	*	*	*

* Required insulation levels for concrete raised floors are R-8 in Climate Zones 2, 11, 13, and 14; R-4 in Climate Zones 12 and 15, and R-0 in Climate Zones 3 through 10.

The required U-factor depends on the type of floor construction: mass and other. The mass floor is distinguished by its heat capacity (HC), which must be greater than 7 (see Heat Capacity discussion in Section 3.1.2G).

Particular note should be taken with this requirement when insulating slab floors that are over unconditioned spaces, such as crawl spaces or parking garages.

Because there are no cavities to accept the insulation, it must be applied either to the underside of the slab or above the slab and beneath the finished floor. There are numerous ways this can be accomplished, but the selection requires careful consideration of the requirements for finishes above or below the insulation.

E. Windows (§143(a)5)

There are three aspects of the Envelope Component Approach for windows:

1. Maximum Area
2. Maximum U-factor
3. Maximum Relative Solar Heat Gain

Under the Envelope Component Approach, the total window area may not exceed 40 percent of the gross wall area for the building (see Section 3.1.2A for the definitions of how these are measured). This maximum area requirement will affect those buildings with very large glass areas, such as automobile showrooms or airport terminals.

Optionally, multiply the length of the display perimeter by six feet in height and use the larger of the product of that multiplication or 40 percent of gross wall area.

Each window or skylight must meet the required U-factor and Relative Solar Heat Gain (see Table 3-20). The required value for Relative Solar Heat Gain (RSHG) is less stringent (higher) for north-facing windows. The "north" value may also be used for windows in the first floor display perimeter which are prevented from having an overhang because of building code restrictions (such as minimum separation from another building or a property line) (exception to §143(a)5.C). Beginning with the 2001 update, the Relative Solar Heat Gain criteria also depends on the window-wall ratio, becoming more stringent with larger window areas.

Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the U-factor and RSHG requirement for the climate zone.

Note also that the RSHG limitation allows credit for window overhangs. In order to get credit for an overhang, it must extend beyond both sides of the window jamb by a distance equal to the overhang projection (§143(a)5.C.ii). This would occur naturally with a continuous eave overhang, but may require special attention in some designs. See Section 3.1.2J for more information on RSHG.

Table 3-20 - Window Requirements

		Climate Zones									
Space Type	Criterion	1,16		3-5		6-9		2,10-13		14, 15	
Nonresidential	U-factor	0.49		0.81		0.81		0.49		0.49	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR[1]	0.49	0.72	0.61	0.61	0.61	0.61	0.47	0.61	0.46	0.61
	11-20% WWR	0.43	0.49	0.55	0.61	0.61	0.61	0.36	0.51	0.36	0.51
	21-30% WWR	0.43	0.47	0.41	0.61	0.39	0.61	0.36	0.47	0.36	0.47
	31-40% WWR	0.43	0.47	0.41	0.61	0.34	0.61	0.31	0.47	0.31	0.40
Residential High-rise	U-factor	0.49		0.49		0.49		0.49		0.49	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR	0.46	0.68	0.41	0.61	0.47	0.61	0.36	0.49	0.36	0.47
	11-20% WWR	0.46	0.68	0.40	0.61	0.40	0.61	0.36	0.49	0.31	0.43
	21-30% WWR	0.36	0.47	0.31	0.61	0.36	0.61	0.31	0.40	0.26	0.43
	31-40% WWR	0.30	0.47	0.26	0.55	0.31	0.61	0.26	0.40	0.26	0.31

1 WWR = Window Wall Ratio

F. Skylights (§143(a)6)

As with windows, there are three aspects of the Envelope Component Approach for skylights:

1. Maximum Area
2. Maximum U-factor
3. Maximum Solar Heat Gain Coefficient

The area limitation for skylights is based on 5 percent of the gross exterior roof area. This effectively prevents large skylights under the Envelope Component Approach. The limit increases to 10 percent for buildings with an atrium over 55 feet high (see Section 3.1.2A for definition). The 55-foot height is also the height limitation at which the Uniform Building Code requires a mechanical smoke-control system for such atriums UBC Sec. 1715). This means that the 10 percent skylight allowance is not allowed for atriums unless they also meet this smoke control requirement. All skylights must meet the maximum U-factor.

Note that skylights are only regulated for SHGC, not RSHG, because skylights cannot have overhangs. With the 2001 update, the SHGC criteria varies with the skylight to roof ratio (SRR). Two ranges are represented in the standard: up to and including 2% of the exterior roof and greater than 2%, but less than or equal to 5%.

Table 3-21 - Skylight Requirements

			Climate Zones				
			1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	U-factor	Glass w/Curb	0.99	1.18	1.18	0.99	0.99
		Glass wo/Curb	0.57	0.68	0.68	0.57	0.57
		Plastic w/Curb	0.87	1.30	1.30	1.10	1.10
	SHGC Glass	0-2% SRR[1]	0.68	0.79	0.79	0.46	0.46
		2.1-5% SRR	0.46	0.40	0.40	0.36	0.36
	SHGC Plastic	0-2% SRR	0.77	0.79	0.77	0.77	0.71
		2.1-5% SRR	0.58	0.65	0.62	0.62	0.58
Residential High-rise	U-factor	Glass w/Curb	0.99	1.18	1.18	0.99	0.99
		Glass wo/Curb	0.57	0.68	0.68	0.57	0.57
		Plastic w/Curb	0.87	1.30	1.30	1.10	0.87
	SHGC Glass	0-2% SRR	0.46	0.58	0.61	0.46	0.46
		2.1-5% SRR	0.36	0.32	0.40	0.32	0.31
	SHGC Plastic	0-2% SRR	0.71	0.65	0.65	0.65	0.65
		2.1-5% SRR	0.55	0.39	0.65	0.34	0.27

1 SRR = Skylight Roof Ratio

For skylights, the U-factor and solar heat gain coefficient (SHGC) criteria is different depending on whether the skylight glazing material is plastic or glass. For glass skylights, the U-factor criteria depends on whether or not the skylight is intended to be mounted on a curb. It is assumed that all plastic skylights are intended to be mounted on a curb. As discussed above, the U-factor for skylights includes heat losses through the glazing, the frame and the curb (when one exists).

G. Exterior Doors §143(a)7)

Opaque doors have no R-value, U-factor or area requirements. Exterior doors are only a part of the compliance process when they are included in the calculation of the gross exterior wall area. Glazing in doors, however, is defined as a window in the *Standards* when glazing exceeds one-half of the area of the door and must be included in all window calculations.

3.2.3 Prescriptive Overall Envelope Approach (§143(b))

The Overall Envelope Approach is the second prescriptive envelope approach. It offers the greater design flexibility of the prescriptive envelope approaches. It allows the designer to make trade-offs between many of the building envelope components. For example, if a designer finds it difficult to insulate the walls to a level adequate for meeting the wall component U-factor requirement, then the insulation level in a roof or floor or the performance of a window component could be increased to offset the under-insulated wall. The same holds true for glazing. If a designer wants to put clear, west-facing glass to enhance the display of merchandise in a show window, it would be possible to use lower SHGC glazing on the other orientations to make up for the increased SHGC on the west.

The Overall Envelope Approach has two parts and both parts must be met: overall heat loss (see Equations 3-2 and 3-3) and overall heat gain (see Equations 3-4 and 3-5). The overall heat loss accounts for the insulating qualities of the building, and sets a maximum rate of conductive heat transfer through the building envelope. The requirements are more stringent in more extreme climate zones than in mild climate zones. The overall heat gains accounts for the area of windows and skylights and their ability to block solar heat gains, thereby reducing cooling loads on the building. Cool roofs are also accounted for in the overall heat gain calculations. The heat gain requirements are more stringent in warmer climate zones.

A *standard value* and a *proposed value* are calculated for both the overall heat loss and the overall heat gain using ENV-2: Overall Envelope Method found in Section 3.3.3. These calculations assume that the standard building complies with the requirements of the Envelope Component Approach (also calculated on ENV-2: Overall Envelope Method). The standard values are compared to the proposed values calculated from the actual envelope design. If the proposed values do not exceed the standard values, then the Overall Building Envelope requirements are met.

Table 3-22 - Nonresidential Requirements (except High-Rise Residential and Hotel/Motel Guest Room)

		Climate Zones									
		1,16		3-5		6-9		2,10-13		14, 15	
Roof/Ceiling											
R-value or		19		19		11		19		19	
U-factor		0.057		0.057		0.078		0.057		0.057	
Wall											
R-value or		13		11		11		13		13	
U-factor											
Wood frame		0.084		0.092		0.092		0.084		0.084	
Metal frame		0.182		0.189		0.189		0.182		0.182	
Mass/7.0≤ HC<15.0		0.340		0.430		0.430		0.430		0.430	
Mass/15.0≤HC		0.360		0.650		0.690		0.650		0.400	
Other		0.084		0.092		0.092		0.084		0.084	
Floor/Soffit											
R-value or		19		11		11		11		11	
U-factor											
Mass/7.0≤HC		0.097		0.158		0.158		0.097		0.158	
Other		0.050		0.076		0.076		0.076		0.076	
Window U-factor		0.49		0.81		0.81		0.49		0.49	
Window Relative Solar Heat Gain		Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
0-10% WWR[1]		0.49	0.72	0.61	0.61	0.61	0.61	0.47	0.61	0.46	0.61
11-20% WWR		0.43	0.49	0.55	0.61	0.61	0.61	0.36	0.51	0.36	0.51
21-30% WWR		0.43	0.47	0.41	0.61	0.39	0.61	0.36	0.47	0.36	0.47
31-40% WWR		0.43	0.47	0.41	0.61	0.34	0.61	0.31	0.47	0.31	0.40
Skylight U-factor	Glass w/Curb	0.99		1.18		1.18		0.99		0.99	
	Glass wo/Curb	0.57		0.68		0.68		0.57		0.57	
	Plastic w/Curb	0.87		1.30		1.30		1.10		1.10	
Skylight SGHC Glass	0-2% SRR[2]	0.68		0.79		0.79		0.46		0.46	
	2.1-5% SRR	0.46		0.40		0.40		0.36		0.36	
Skylight SHGC Plastic	0-2% SRR	0.77		0.79		0.77		0.77		0.71	
	2.1-5% SRR	0.58		0.65		0.62		0.62		0.58	

1 WWR = Window Wall Ratio

2 SRR= Skylight Roof Ratio

Table 3-23 - High-Rise Residential and Hotel/Motel Guest Room Requirements

	Climate Zones									
	1,16		3-5		6-9		2,10-13		14, 15	
Roof/Ceiling										
R-value or	30		19		19		30		30	
U-factor	0.037		0.051		0.051		0.037		0.037	
Wall										
R-value or	19		11		11		13		13	
U-factor										
Wood frame	0.063		0.092		0.092		0.084		0.084	
Metal frame	0.140		0.181		0.181		0.175		0.175	
Mass/7.0≤ HC<15.0	0.340		0.430		0.430		0.430		0.430	
Mass/15.0≤HC	0.360		0.650		0.690		0.650		0.400	
Other	0.063		0.092		0.092		0.084		0.084	
Floor/Soffit										
R-value or	19		11		11		11		11	
U-factor										
Mass/7.0≤HC	0.097		0.158		0.158		0.097		0.097	
Other	0.050		0.076		0.076		0.076		0.076	
Raised concrete R-value	8		*		*		*		*	
Window U-factor	0.49		0.49		0.49		0.49		0.49	
Window Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
0-10% WWR[1]	0.46	0.68	0.41	0.61	0.47	0.61	0.36	0.49	0.36	0.47
11-20% WWR	0.46	0.68	0.40	0.61	0.40	0.61	0.36	0.49	0.31	0.43
21-30% WWR	0.36	0.47	0.31	0.61	0.36	0.61	0.31	0.40	0.26	0.43
31-40% WWR	0.30	0.47	0.26	0.55	0.31	0.61	0.26	0.40	0.26	0.31
Skylight U-factor Glass w/Curb	0.99		1.18		1.18		0.99		0.99	
Glass wo/Curb	0.57		0.68		0.68		0.57		0.57	
Plastic w/Curb	0.87		1.30		1.30		1.10		0.87	
Skylight SGHC Glass 0-2% SRR[2]	0.46		0.58		0.61		0.46		0.46	
2.1-5% SRR	0.36		0.32		0.40		0.32		0.31	
Skylight SHGC Plastic 0-2% SRR	0.71		0.65		0.65		0.65		0.65	
2.1-5% SRR	0.55		0.39		0.65		0.34		0.27	

* Required insulation levels for concrete raised floors are R-8 in Climate Zones 2, 11, 13, and 14; R-4 in Climate Zones 12 and 15, and R-0 in Climate Zones 3 through 10.

1 WWR = Window Wall Ratio

2 SRR= Skylight Roof Ratio

Associated with the increased design flexibility afforded by the Overall Envelope Approach is an increase in complexity of the calculations when demonstrating compliance. Special attention must be given to the calculations because the effects of all the envelope components are interrelated. Changing any one component may prevent the overall envelope from complying. Improvements to one or more of the other components will be needed to bring the envelope into compliance.

Equation 3-2– Standard Building Heat Loss

$$HL_{std} = \sum_{i=1}^{nW}\left(A_{Wi} \times U_{Wi_{std}}\right) + \sum_{i=1}^{nF}\left(A_{Fi} \times U_{Fi_{std}}\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}}\right) + \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}}\right) + \sum_{i=1}^{nS}\left(A_{Si} \times U_{Si_{std}}\right)$$

Where

HL_{std} = Overall heat loss of the standard building (in Btu/h-°F).

i = Each wall type and orientation, floor/soffit type, roof/ceiling type, window and glazed door (glazing and frame) type and orientation, or skylight type for the standard building.

nW, nR,

nG, nF

nS = Number of components of the applicable envelope feature.

A_{Wi} = Exterior wall area on the north, east, south, and west orientations of the proposed building (in ft.^{2}) including the window area on that orientation of the proposed building, minus A_{Gi}. The standard building has as many walls in each orientation as there are HC categories in that orientation of the proposed building.

A_{Fi} = Exterior floor/soffit area of the proposed building (in ft.^{2}). The standard building has as many floors/soffits as there are HC categories in the floors/soffits of the proposed building.

A_{Ri} = Exterior roof/ceiling area of the proposed building (in ft.^{2}) plus the skylight area of the proposed building, less A_{Si}.

A_{Gi} = Window (glazing) area of each type on the north, east, south, and west orientations of the standard building (in ft.^{2}). If the total window wall ratio of the proposed building is more than 40 percent, the total window area is the greater of (a) 40 percent of the gross exterior wall area, or (b) six feet times the display perimeter.

The window area of each type and on each orientation of the standard design shall be decreased in proportion to the area in the proposed design according to one of the following formulas as applicable:

(a)

$$A_{Gi-adj} = \frac{A_{Gi-prop}}{A_{Gtotal-prop}} x0.40xA_{Wtotal-prop}$$

(b)

$$A_{Gi-adj} = \frac{A_{Gi-prop}}{A_{Gtotal-prop}} x(6\ x\ Display\ Perimeter)$$

If the total window area of the proposed building is less than 10 percent of the gross exterior wall area, the window area of each type and on each orientation of the standard design shall be increased in proportion to the area in the proposed design according to the following formula:

$$A_{Gi-adj} = \frac{A_{Gi-prop}}{A_{Gtotal-prop}} x0.10xA_{Wtotal-prop}$$

Where:

$A_{Gi\text{-}adj}$ = Adjusted window area of each type on the north, east, south, and west orientations (in ft.^{2}).

$A_{Gi\text{-}prop}$ = Actual proposed window area of each type in the respective orientation (in ft.^{2}).

$A_{Gtotal\text{-}prop}$ = Total actual proposed window area of the proposed building (in ft.^{2}).

$A_{Wtotal\text{-}prop}$ = Total actual proposed gross exterior wall area of the proposed building (in ft.^{2}).

A_{Si} = Skylight area of the standard building for each skylight type (in ft.^{2}). The total skylight area in the standard building is equal to the total skylight area of the proposed building or five percent of the gross exterior roof area (or, for atria over 55 feet high, 10 percent of the gross exterior roof area), whichever is less. If the total skylight area of the proposed building is more than five percent of the gross exterior roof area or more than 10 percent of the gross exterior roof area for atria over 55 feet high, the skylight area of each type of the standard building shall be decreased in proportion to the area in the proposed design according to the following formula:

$$A_{Si-adj} = \frac{A_{Si-prop}}{A_{Stotal-prop}} x0.10xA_{Rtotal-prop}$$

for atria over 55 feet high, and

$$A_{Si-adj} = \frac{A_{Si-prop}}{A_{Stotal-prop}} x0.05xA_{Rtotal-prop}$$

for others, where:

$A_{Si\text{-}adj}$ = Adjusted skylight area of each type (in ft.^{2}).

$A_{Si\text{-}prop}$ = Actual proposed skylight area of each type (in ft.^{2}).

$A_{Stotal\text{-}prop}$ = Total actual proposed skylight area of the proposed building (in ft.^{2}).

$A_{Rtotal\text{-}prop}$ = Total actual proposed gross exterior roof area of the proposed building (in ft.^{2}).

U_{Wistd} = The applicable wall U-value for the corresponding AWi from Table 1-H or 1-I.

U_{Fistd} = The applicable floor/soffit U-value for the corresponding AFi from Table 1-H or 1-I.

U_{Ristd} = The applicable roof/ceiling U-value for the corresponding ARi from Table 1-H or 1-I.

U_{Gistd} = The applicable window U-value for the corresponding AGi from Table 1-H or 1-I.

U_{Sistd} = The applicable skylight U-value for the corresponding ASi from Table 1-H or 1-I.

A. Overall Heat Loss

There are two parts to the Overall Heat Loss calculation. The first is to calculate the Standard Building Heat Loss; this becomes the standard that must be met. The second is to calculate the Proposed Building Heat Loss, which is compared to the standard to show that it does not exceed the Standard Building Heat Loss.

There are three steps to calculating the Standard Building Heat Loss:

Step 1 - Calculate areas of each type of envelope assembly (walls, windows, roofs, etc.). If glazing is too large or small, areas may require adjustment as directed on the ENV-2.

Step 2 - Determine allowed U-factors from Table 3-22 and Table 3-23.

Step 3 - Multiply and add to get Standard Building Heat Loss.

Each step will be discussed in turn.

Calculate Areas

First, identify each type of assembly in the building envelope. In a complex building, there could be many. Assemblies are different if they have different materials or thermal properties. For example, a steel stud framed wall with a 1" stucco exterior would be different from a steel stud framed wall with 4" brick cladding.

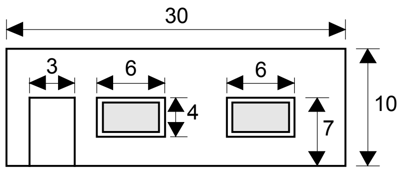
Next, calculate the areas of each assembly. All dimensions are taken at the exterior surface of the assembly. The sum of all the vertical surface areas is the gross exterior wall area (walls, windows, doors). The exterior wall area is the opaque wall area only (no doors). The window wall ratio is the total window area in the gross exterior walls, divided by the gross exterior wall area.

In the case of windows, the area is based on the rough opening dimensions. For most buildings, the actual window area is used to calculate the Standard Building Heat Loss.

Example 3-4– Area Calculation

Question

How is exterior wall area calculated for the following wall (dimensions in feet)?



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The door area is 3 x 7 = 21 ft^2. The window areas are 6 x 4 = 24 ft^2 each, or 48 ft^2 total. The exterior wall area is the gross minus doors and windows, or 300 ft^2 — 21 ft^2 — 48 ft^2 = 231 ft^2.

Adjust Areas

When the window wall ratio is less than 10 percent or more than 40 percent, an adjusted window area is used to calculate the Standard Building Heat Loss.

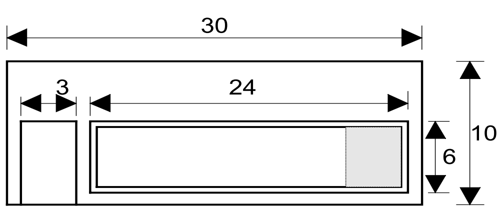
The first adjustment is for buildings with very little window area. The *Standards* allow for a minimum of 10 percent window wall ratio in calculating the standard envelope heat loss (“A_{Gi}" of Equation 3-2). If the actual window wall ratio is less than 10 percent, then an area equal to 10 percent of the gross exterior wall area is used for the standard building.

The second adjustment is for buildings with very large window area. If the actual window wall ratio is greater than 40 percent, then an area equal to 40 percent of the gross wall area is used to calculate the Standard Building Heat Loss. Alternatively, for buildings with substantial display perimeter areas (see 3.1.2A), an area equal to six feet high by the length of the display perimeter is calculated. If this value is greater than 40 percent of the gross exterior wall area, then it is used in the standard envelope heat loss calculation (“A_{Gi}” of Equation 3-2).

Example 3-5– Glazing Area Adjustments

Question

What is the window wall ratio (WWR) for the following wall (dimensions in feet)? How is the window and wall area adjusted under the overall envelope approach?



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The window area is 24 x 6 = 144 ft^2. The WWR is 144 / 300 = 0.48, or 48 percent. The exterior wall area is 300 — 144 = 156 ft^2. The window area must be adjusted downward to 40 percent of the gross exterior wall area, or 0.40 x 300 = 120 ft^2. This is a window area reduction of 144 —120 = 24 ft^2. The exterior wall area must be increased by the same amount to 156 + 24 = 180 ft^2 (as shown by shaded area in sketch above).

If either of these adjustments is made to the standard window area, the exterior wall area is also adjusted (see Example 3-4). Skylights are treated similarly (“A_{Si}” of Equation 3-2). The actual skylight area or the rough opening area will be used to calculate the standard envelope heat loss. If the skylight is site-built (as in the case of large atrium roofs, malls, or other applications) and its shape is three-dimensional (not flat), then the area is the actual surface area, not the opening area (see definition of **Skylight Area** under Section 3.1.2A). If the skylight area is larger than 5 percent of the gross exterior roof area (roof doors not included for the standard building), then an area equal to 5 percent of the roof area is used. Alternatively, if the building has an atrium over 55 feet high, then the allowance for skylights are increased to 10 percent (or the actual skylight area if less than 10 percent of the gross roof area).

Determine Allowed U-factors

The allowed U-factors are taken from Table 3-22 and Table 3-23, depending on the occupancy type. These are the same values discussed under the Envelope Component Approach in the previous Section 3.2.2. It is necessary to differentiate wall assembly types and floor/soffit assembly types. The U-factor requirements depend on framing type and heat capacity of the wall or the floor/soffit. In the case of heavier construction assemblies, the heat capacity (see Section 3.1.2G) must be calculated before the allowed U-factor can be determined.

Multiply and Add

Once the areas and allowed U-factors are determined for each assembly, then the Standard Building Heat Loss can be calculated. For each assembly, the U-factor (U) and area (A) are multiplied together; the result is known as the *UA product* for the assembly. If any of the areas were adjusted, then the adjusted areas are used in this calculation. These UA products are added to obtain the total UA product for the building, which is the Standard Building Heat Loss.

The Standard Building Heat Loss has units of Btu/hr-°F, and it describes the amount of heat lost per hour through the building envelope for every degree Fahrenheit of temperature difference between inside and outside, under steady state heat flow conditions.

Equation 3-3– Proposed Building Heat Loss

$$HL_{prop} = \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}}\right) + \sum_{j=1}^{nF}\left(A_{Fj} \times U_{Fj_{prop}}\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}}\right) + \sum_{j=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}}\right) + \sum_{j=1}^{nS}\left(A_{Sj} \times U_{Sj_{prop}}\right)$$

Where

HL_{prop} = Overall heat loss of the proposed building (in Btu/h-°F).

j = Each wall type and orientation, floor/soffit type, roof/ceiling type, window and glazed door (glazing and frame) type and orientation, or skylight type for the proposed building.

nW, nR,

nG, nF,

nS = As determined in Equation 3-2.

A_{Wj} = Exterior wall area on the north, east, south, and west orientations of the proposed building (in ft.2). Each orientation has as many walls as there are HC categories.

A_{Fj} = Exterior floor/soffit area of the proposed building (in ft.2). There are as many floors/soffits as there are HC categories.

A_{Rj} = Exterior roof/ceiling area of the proposed building (in ft.2).

A_{Gj} = Window (glazing) area for each window type and orientation of the proposed building (in ft.2).

A_{Sj} = Skylight area for each skylight type of the proposed building (in ft.2).

U_{Wjprop} = The wall U-value for the corresponding A_{Wj}.

U_{Fjprop} = The floor/soffit U-value for the corresponding A_{Fj}.

U_{Rjprop} = The roof/ceiling U-value for the corresponding A_{Rj}.

U_{Gjprop} = The window U-value for the corresponding A_{Gj}.

U_{Sjprop} = The skylight U-value for the corresponding A_{Sj}.

Once the Standard Building Heat Loss rate is determined, the proposed design's heat loss rate can be calculated and the two can be compared. If the proposed heat loss rate does not exceed the standard, then the envelope complies with the heat loss criteria.

The proposed heat loss is calculated the same as the standard, except that the actual areas and U-factors of each assembly are used without adjustment. The actual U-factors are calculated as described in section 3.1.2C-F. It is not necessary to calculate the U-factor of opaque doors, as they are ignored in the overall heat loss calculations. Any glazing in doors, however, is considered a window and must be included in all window calculations.

The UA product is calculated for each surface, and these are totaled to arrive at the Proposed Building Heat Loss. It has the same units and meaning as the Standard Building Heat Loss (see above).

For a complete example of how the Standard Building Heat Loss and Proposed Building Heat Loss are calculated and compared using the ENV-2 form (see Section 3.3.2).

B. Overall Heat Gain

As with the overall heat loss, there are two parts to the Overall Heat Gain calculation. The first part is to calculate the Standard Building Heat Gain; this becomes the standard that must not be exceeded.

The second part is to calculate the Proposed Building Heat Gain; compare this to the standard and show that the proposed heat gain does not exceed the standard heat gain.

Equation 3-4– Standard Building Heat Gain

$$\begin{aligned} HG_{std} = {} & \sum_{i=1}^{nW}\left(A_{Wi} \times U_{Wi_{std}} \times TF_i\right) + \sum_{i=1}^{nF}\left(A_{Fi} \times U_{Fi_{std}} \times TF_i\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}} \times TF_i\right) \\ & + \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}} \times TF_i\right) + \sum_{i=1}^{nS}\left(A_{Si} \times U_{Si_{std}} \times TF_i\right) + \sum_{i=1}^{nG}\left(WF_{Gi} \times A_{Gi} \times RSHG_{Gi_{std}}\right) \times SF \\ & + \sum_{i=1}^{nS}\left(WF_{Si} \times A_{Si} \times SHGC_{Si_{std}}\right) \times SF + \sum_{i=1}^{nR}\left(WF_{Ri} \times A_{Ri} \times U_{Ri_{std}} \times \alpha_{Ristd}\right) \times SF \end{aligned}$$

Where

HG_{std} = Overall heat gain of the standard building (Btu/h).

i = As determined in Equation 3-2.

nW, nR,

nG, nF,

nS = As determined in Equation 3-2.

A_{Wi} = As determined in Equation 3-2.

A_{Fi} = As determined in Equation 3-2.

A_{Ri} = As determined in Equation 3-2.

A_{Gi} = As determined in Equation 3-2.

A_{Si} = As determined in Equation 3-2.

U_{Wistd} = As determined in Equation 3-2.

U_{Fistd} = As determined in Equation 3-2.

U_{Ristd} = As determined in Equation 3-2.

U_{Gistd} = As determined in Equation 3-2.

U_{Sistd} = As determined in Equation 3-2.

$RSHG_{Gistd}$ = The applicable relative solar heat gain for the corresponding A_{Gi}, from Table 3-21, Table 3-22 or Table 3-23 (unitless).

W_n, W_e,

W_s, WF_{Gi} = The applicable weighting factor for glazing for each orientation of the standard building, from Table 3-25 (unitless).

WF_{Si} = The applicable weighting factor for skylight of the standard building, from Table 3-25 (unitless).

WF_{Ri} = The applicable weighting factor for roof of the standard building, from Table 3-25 (unitless).

a_{Ristd} = A standard roof absorptivity of 0.70 for the corresponding A_{Ri}.

$SHGC_{Sistd}$ = The applicable solar heat gain coefficient for the corresponding A_{Si}, from Table 3-22 or Table 3-23 (unitless).

SF = The solar factor from Table 3-24.

TF_i = The temperature factor from Table 3-24.

There are four steps to calculating the Standard Building Heat Gain:

Step 1 - Calculate the area and determine the U-factor and temperature factor (Table 3-24) of each type of envelope assembly (walls, windows, roofs, etc.) [Same values as heat loss equations.] Window areas may require adjustment if too large or small.

Step 2 - Determine RSHG for north and non-north orientations, and SHGC for skylights (as per climate zone, occupancy and type); values are taken from Table 3-22 and Table 3-23.

Step 3 - Determine the weighting factors and solar factors for each orientation (as per climate zone) from Table 3-24.

Step 4 - Determine the applicable roof absorptivity value. This value is set at 0.7 for standard roofs (all roofs other than cool roofs).

Step 5 - Multiply and add to get Standard Building Heat Gain.

Each step will be discussed in turn.

Calculate Areas

The total area of envelope features and glazing and corresponding U-factors were determined earlier for the Standard Building Heat Loss calculation. A temperature factor (Table 3-24) is applied. Window area was adjusted when it was too large or too small for the standard area. This same total is used for the Standard Building Heat Gain Calculation, except that it is further broken down by orientation. Each window is assigned to the nearest cardinal orientation: east, west, north and south (see Section 3.1.2). A solar factor (Table 3-24) is applied to window and skylight areas.

As in the heat loss calculation, the window areas are calculated by the rough opening dimensions.

Adjust Areas

If the total window area was adjusted in the standard heat loss calculation, a similar adjustment is made here, except that it is applied to each orientation. For example, if the proposed window wall ratio is 50 percent, then the window must be reduced to 40 percent for the standard reduction. This translates to the glazing area on each orientation being reduced by 20 percent for the standard heat gain calculation.

Determine RSHG and SHGC

The values for RSHG and SHGC are found in Table 3-22 and Table 3-23. For windows, the standard relative solar heat gain (RSHG) differs depending on whether or not the window is north-facing (see Sections 3.1.2A, I and J for definitions). For skylights, the standard solar heat gain coefficient (SHGC) differs depending on whether the skylight glazing material is glass or plastic It also differs based on the ratio of its area to the gross exterior roof area- there are two categories for this ratio (0-2% and 2.1-5%).

The values of RSHG and SHGC also differ by climate zone. For the milder climate zones, 1, 3-9, and 16, higher values are allowed.

For the Standard Building Heat Gain calculation, the values of RSHG and SHGC are simply taken from the tables and entered into the calculations.

Example 3-6– RSHG Determination

Question

What is the RSHG value for an east-facing window in an office building in climate zone 8 if the WWR is 8%?

Answer

0.61 (Table 3-22)

Determine Temperature Factor

The temperature factor considers the effects of solar radiation striking envelope surfaces. The appropriate values are taken from Table 3-24 and entered into the calculations.

Table 3-24 - Temperature and Solar Factors

Climate Zone	Temperature Factor (TF) Envelope Construction			Solar Factor (SF) (Btu/hr. x ft.^{2})
	Light Mass	Medium Mass	Heavy Mass	
1	14	3	1	128
2	40	30	28	126
3	28	18	16	126
4	32	22	20	125
5	27	17	15	124
6	28	18	16	123
7	27	17	15	123
8	33	23	21	123
9	42	31	29	123
10	45	35	33	123
11	49	38	36	127
12	45	34	32	126
13	45	35	33	125
14	52	42	40	125
15	55	45	43	123
16	34	23	21	128

Light Mass: Heat Capacity < 7 Btu/ft²-°°F
Medium Mass: Heat Capacity >= 7 and
Heavy Mass: Heat Capacity >= 15

Determine Weighting Factors

Weighting factors in the heat gain equations account for the variation in solar radiation striking windows and skylights by orientation and climate zone. The appropriate values are taken from Table 3-25 and entered into the Envelope Form ENV-2 Part 5 of 6. For windows assume Light Mass value.

Table 3-25- Glazing Orientation and Roof Weighting Factors

Space Type	Climate Zone	WF_{north}	WF_{south}	WF_{west}	WF_{east}	WF_{sky}	WF_{roof}
Nonresidential	1	0.56	1.25	1.16	1.03	1.48	0.93
	2	0.56	1.30	1.18	0.96	2.34	1.12
	3	0.51	1.28	1.24	0.97	2.42	0.84
	4	0.55	1.20	1.24	1.01	2.53	0.96
	5	0.58	1.25	1.18	0.98	2.48	0.80
	6	0.56	1.23	1.21	1.00	2.40	0.84
	7	0.57	1.30	1.17	0.97	2.36	0.87
	8	0.60	1.26	1.14	1.00	2.47	0.98
	9	0.56	1.36	1.11	0.97	2.29	0.97
	10	0.60	1.38	1.07	0.95	2.19	1.02
	11	0.55	1.19	1.17	1.10	2.37	0.89
	12	0.55	1.17	1.21	1.07	2.40	0.92
	13	0.58	1.15	1.17	1.10	2.39	1.04
	14	0.57	1.17	1.20	1.07	2.46	1.13
	15	0.61	1.27	1.05	1.07	2.29	0.92
	16	0.51	1.27	1.15	1.07	2.20	1.03
Residential High-rise	1	0.50	1.24	1.23	1.03	1.36	0.82
	2	0.55	1.29	1.23	0.94	2.30	1.08
	3	0.47	1.28	1.29	0.96	2.42	0.80
	4	0.54	1.17	1.33	0.96	2.53	0.96
	5	0.49	1.28	1.25	0.97	2.48	0.77
	6	0.55	1.20	1.26	0.99	2.37	0.79
	7	0.55	1.28	1.21	0.96	2.37	0.88
	8	0.57	1.26	1.20	0.97	2.44	0.96
	9	0.53	1.39	1.14	0.94	2.24	0.93
	10	0.59	1.34	1.12	0.94	1.92	1.00
	11	0.53	1.14	1.27	1.06	2.23	0.88
	12	0.55	1.14	1.29	1.03	2.31	0.91
	13	0.57	1.12	1.27	1.05	2.27	1.02
	14	0.57	1.13	1.28	1.02	2.38	1.08
	15	0.59	1.26	1.12	1.03	2.26	0.90
	16	0.49	1.24	1.25	1.01	2.02	0.95

Example 3-7– Determining Weighting Factors

Question

What is the weighting factor for a south-facing window in climate zone 12 for an office building?

Answer

1.17 (Table 3-25)

Determine Solar Factor

The solar factor is used to account for solar radiation striking glazed surfaces. The appropriate values are taken from Table 3-24 and entered into the standard and proposed heat gain calculations.

Determine Roof Absorptivity Value

The roof absorptivity value accounts for solar radiation absorbed through the roof surface. A value of 0.7 is used for the standard building. For the proposed building, a value of 0.45 is used for eligible cool roofs and a value of 0.7 is used for standard roofs (all roofs other than cool roofs).

Eligible tile cool roofs are roofs tested to have a solar reflectance of 0.4 or greater and a thermal emittance of 0.75 or greater. Eligible single ply or liquid applied cool roofs are roofs tested to have a solar reflectance of 0.70 or greater and a thermal emittance of 0.75 or greater. Eligible liquid applied cool roofs will also have a thickness greater than 20 mils and meet minimum performance requirements.

Eligible cool roof packaging will contain a label listing these testing results.

Multiply and Add

Once the areas and the allowed RSHG, SHGC and weighting factor are determined for each glazing orientation, then the Standard Building Heat Gain can be calculated. For each window orientation, the adjusted area is multiplied by the RSHG value and the weighting factor. For each type of skylight, the adjusted areas are multiplied by the SHGC value and the weighting factor. If the window or skylight area was adjusted, the adjusted areas are used in this calculation. All of these products are added to obtain the Standard Building Heat Gain.

Once the Standard Building Heat Gain rate is determined, the proposed design heat gain rate can be calculated and the two can be compared. If the proposed heat gain rate does not exceed the standard, then the envelope complies with the heat gain criteria.

The proposed heat gain is calculated the same as the standard, except that the actual areas for each orientation, and the actual RSHG and SHGC are used. The determination of actual SHGC and RSHG are described above in Sections 3.1.2I and 3.1.2J.

For the windows on each orientation, the actual area, SHGC, overhang factor and weighting factor are multiplied together. For skylights, the actual area, SHGC and weighting factor are multiplied. For roofs, the actual area, U-factor, weighting factor and absorptivity value are multiplied. These are summed to obtain the Proposed Building Heat Gain.

Equation 3-5– Proposed Building Heat Gain

$$\begin{aligned} HG_{prop} = & \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}} \times TF_j\right) + \sum_{j=1}^{nF}\left(A_{Fj} \times U_{Fj_{prop}} \times TF_j\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}} \times TF_j\right) \\ & + \sum_{j=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}} \times TF_j\right) + \sum_{j=1}^{nS}\left(A_{Sj} \times U_{Sj_{prop}} \times TF_j\right) + \sum_{j=1}^{nG}\left(WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j\right) \times SF \\ & + \sum_{j=1}^{nS}\left(WF_{Sj} \times A_{Sj} \times SHGC_{Sj_{prop}}\right) \times SF + \sum_{j=1}^{nR}\left(WF_{Rj} \times A_{Rj} \times U_{Rj_{prop}} \times \alpha_{Rj_{prop}}\right) \times SF \end{aligned}$$

Where

HG_{prop} = Overall heat gain of the proposed building (Btu/h).

j = As determined in Equation 3-3.

nW, nR,

nG, nF,

nS = As determined in Equation 3-3.

A_{Wj} = As determined in Equation 3-3.

A_{Fj} = As determined in Equation 3-3.

A_{Rj} = As determined in Equation 3-3.

A_{Gj} = As determined in Equation 3-3.

A_{Sj} = As determined in Equation 3-3.

U_{Wjprop} = As determined in Equation 3-3.

U_{Fjprop} = As determined in Equation 3-3.

U_{Rjprop} = As determined in Equation 3-3.

U_{Gjprop} = As determined in Equation 3-3.

U_{Sjprop} = As determined in Equation 3-3.

$SHGC_{Gj}$ = The solar heat gain coefficient for the corresponding A_{Gj} (unitless)

$SHGC_{Sj}$ = The solar heat gain coefficient for the corresponding A_{Sj} (unitless).

OHF_{Gj} = The overhang factor for the corresponding A_{Gj} (unitless).

$OHF_{Gj} = 1 + aH/V + b(H/V)^2$

Where:

H = Horizontal projection of an overhang from the surface of the window, no greater than V, in feet.

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

a = -0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east- and west-facing windows.

b = 0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east and west-facing windows.

WF_{Gj} = The applicable weighting factor for each orientation of the building, from Table 3-25 (unitless).

WF_{Skyj} = The applicable weighting factor for skylight of the proposed building, from Table 3-25

WF_{Rj} = The applicable weighting factor for roof of the proposed building, from Table 3-25 (unitless).

a_{Rjstd} = The applicable roof absorptivity for the corresponding A_{Rj}. An absorptivity of 0.45 for cool roofs (as defined in §118). An absorptivity of 0.7 for all other roofs.

SF = The solar factor from Table 3-24.

TF_j = The temperature factor from Table 3-24.

For an example of how the Standard and Proposed Building Heat Gain are calculated and compared using the ENV-2 form (see Section Example 3-9).

Example 3-8– Determining Roof Absorptivity Value

Question

What roof absorptivity value should be used in the proposed design for a single ply roofing product labeled with a tested reflectance of 0.8 and tested emittance of 0.4?

Answer

0.7 (Tested emittance does not meet the requirement for an eligible cool roof)

Example 3-9 – Overall Envelope Approach

Question

A proposed building in San Diego is designed with single clear glass, which does not meet the prescriptive criteria for fenestration U-factor or SHGC. The building owner would prefer to upgrade insulation levels in the roofs and walls, rather than install double glass. Is it possible to comply with the *Standards* using this overall envelope method?

The building is two stories with 50,000 ft² of roof area and 180,000 ft² of gross wall area. The building has slab-on-grade floor construction. Exterior walls are constructed of 2x6 metal studs spaced at 16 in. on center. R-19 batt insulation is installed in the cavity and R-7 continuous insulation is installed on the exterior of the wall. The roof construction consists of 2x12 joists with R-38 insulation in the cavity. The roof qualifies as a cool roof with an initial reflectance greater than 0.70 and an emissivity greater than 0.75.

Fenestration area totals 18,000 ft² with 5,000 ft² on the north and south and 4,000 ft² on the east and west. The SHGC of the fenestration assembly is 0.78 and the U-factor is 1.22. All of the 5 ft high windows are shaded by overhangs with a 4 ft projection, located at the top of the window.

Answer

The Overall Envelop Approach can be used to demonstrate compliance. It is necessary to show that the proposed building has both a lower heat loss and a lower heat gain than a standard building that meets the minimum requirements of the prescriptive standards. Heat loss and heat gain are calculated using the equations from §143(b).

Heat loss for the standard building is 49,098 Btu/h-ºF as shown in the calculations below. The U-factors are taken from Table 3-22. The wall U-factor is based on a metal framed wall.

$$HL_{std} = \sum_{i=1}^{nW}\left(A_{Wi} \times U_{Wi_{std}}\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}}\right) + \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}}\right)$$

HL_{std} = 162,000x0.189 + 50,000x0.078 + 18,000x0.81

HL_{std} = 49,098 Btu/h-ºF

Heat loss for the proposed building is 35,610 Btu/h-ºF as shown in the calculations below. The wall and roof U-factors (0.075 and 0.039 respectively) are taken from Appendix B. The window U-factor of 1.22 is taken from NFRC ratings.

$$HL_{prop} = \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}}\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}}\right) + \sum_{j=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}}\right)$$

HL_{prop} = 162,000x0.075 + 50,000x0.030 + 18,000x1.22

HL_{prop} = 35,610 Btu/h-ºF

The proposed building has a lower heat loss than the standard building so the building meets the heat loss portion of the requirements. Next, the heat gain must be compared for both the proposed and standard building.

The heat gain for the standard building is 2,961,571 Btu/h as shown in the calculations below. The SHGC criteria for fenestration is 0.61 for all orientations (see Table 3-22).

$$\begin{aligned} HG_{std} = {} & \sum_{i=1}^{nW}\left(A_{Wi} \times U_{Wi_{std}} \times TF_i\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}} \times TF_i\right) \\ & + \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}} \times TF_i\right) + \sum_{i=1}^{nG}\left(WF_{Gi} \times A_{Gi} \times RSHG_{Gi_{std}}\right) \times SF \\ & + \sum_{i=1}^{nR}\left(WF_{Ri} \times A_{Ri} \times U_{Ri_{std}} \times \alpha_{Ri_{std}}\right) \times SF \end{aligned}$$

HG_{Std} = (162,000x0.189x27)

+(50,000x0.078x27)

+(18,000x0.81x27)

+[(0.57x5,000x0.61)+(0.97x4,000x0.61)+(1.30x5,000x0.61)+(1.17x4,000x0.61)]x123

+(0.87x50,000x0.078x0.70)x123

HG_{Std} = 2,961,571 Btu/h

The heat gain for the proposed building is 1,935,480Btu/h as shown in the calculations below. Note that the roof absorptance is entered as 0.45, the value prescribed for qualifying cool roofs.

$$HG_{prop} = \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}} \times TF_j\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}} \times TF_j\right)$$
$$+ \sum_{j=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}} \times TF_j\right) + \sum_{j=1}^{nG}\left(WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j\right) \times SF$$
$$+ \sum_{j=1}^{nR}\left(WF_{Rj} \times A_{Rj} \times U_{Rj_{prop}} \times \alpha_{Rj_{prop}}\right) \times SF$$

HG_{Prop} = (162,000x0.075x27)

+(50,000x0.030x27)

+(18,000x1.22x27)

+[(0.57x5,000x0.78x0.80)+(0.97x4,000x0.78x0.49)+(1.30x5,000x0.78x0.45)+(1.17x4,000 x0.78x0.49)]x123

+(0.87x50,000x0.030x0.45)x123

HG_{Prop} = 1,935,480 Btu/h

Since both the heat gain and heat loss of the proposed building is less than the standard building, the proposed building complies using the overall envelope approach.

3.2.4 Performance Approach

Under the performance approach, the energy use of the building is modeled using an energy budget generated by a computer program approved by the Energy Commission call the Energy Hotline for the latest version. This section presents some basic details on the modeling of building envelope components. *Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program.* All computer programs, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Section 6.1.

A. Modeling Envelope Components

The following modeling capabilities are required by all approved nonresidential computer programs. These modeling features affect the thermal loads seen by the HVAC system model.

Opaque Surface Mass Characteristics

Heat absorption, retention and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled. Typical inputs are thickness, density, specific heat and conductivity. See Section 3.1.2G for determining the heat capacity of materials.

Opaque Surface Heat Transfer

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

- Surface areas by opaque surface type. Section 3.1.2A discusses determining the area of opaque surfaces.
- Surface orientation and slope. Section 3.1.2A discusses how slope affects wall and roof/ceiling definitions.
- Thermal conductance of the surface. Section 3.1.2C through G discusses determining the U-factor of various assemblies.
- Surface absorptance. Surface absorptance is a restricted input (except for cool roofs). Section 6.1.3A discusses fixed and restricted modeling assumptions. Surface absorptance is a variable input in proposed design for roofs to provide a 'cool roof credit'. The roof reference design is set with a non-cool roof surface absorptance. The difference in surface absorptance creates a credit that can be used with both the building envelope trade-off option and the whole building performance method. Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance ensures that when the roof does warm up, its heat can escape through radiation to the sky.

Glazing Heat Transfer

Heat transfer through all glazed surfaces of the building envelope are modeled using the following inputs:

- Glazing areas. Section 3.1.2A discusses determining the area of windows and skylights.
- Glazing orientation and slope. Section 3.1.2A discusses how slope affects window and skylight definitions.
- Glazing thermal conductance. Section 3.1.2I discusses how to determine the fenestration U-factor.
- Glazing solar heat gain coefficient. Section 3.1.2J discusses how to determine the solar heat gain coefficient of glazing.

Overhangs

Approved computer programs are able to model overhangs. Typical inputs are overhang projection, height above window, window height and the overhang horizontal extension past the edge of the window. If the overhang horizontal extension (past the window jambs) is not an input, then the program must assume that the extension is zero (i.e., overhang width is equal to window width) which results in no benefits from the overhang.

Interzone Surfaces

Heat transfer modeled through all surfaces separating different space conditioning zones may be modeled with inputs such as surface area, surface tilt and thermal conductance. Thermal mass characteristics may be modeled using the thickness, specific heat, density and types of layers that comprise the construction assembly.

3.2.5 Alterations

Alterations to the envelope of an existing conditioned space have the following options for showing compliance:

Option 1. Show that the overall heat gain and heat loss of the building is not increased. This can be demonstrated on form ENV-2, Overall Envelope Method, Part 2 of 6 and Part 3 of 6 by showing the heat gain and heat loss for the altered component(s) before and after the alteration; or

Option 2. Meet current prescriptive envelope requirements for the altered component; or

Note: The prescriptive solar heat gain coefficient requirements do not apply to fenestration repaired, replaced, or up to 50 square feet of new glass.

Option 3. Use an approved computer program to show compliance with an energy budget for the altered space; or

Option 4. Use an approved computer program to show that the energy use of the entire building is what it would be if the remainder of the building was unaltered and the altered space complied with its energy budget ("existing plus alteration"). This fourth option involves four steps and three separate computer runs:

Step 1. Model the building before any alterations or additions to determine the energy use of the existing building (use the value referred to as the "proposed" energy use).

Step 2. Model the new or altered space to determine the energy budget ("standard" design) of the alteration or addition alone.

Step 3. Calculate the energy budget for the entire building as indicated in Equation 3-6.

Equation 3-6– Energy Use Goal

$$\frac{(A_e \cdot PD_e) + (A_a \cdot SD_a)}{A_{e+a}} = \text{Energy Use Goal}$$

Where:

A_e = Area of the existing entire building before the proposed addition/alteration (from Step 1. above)

PD_e = Proposed design of the existing entire building before the proposed addition/alteration (from Step 1. above)

A_a = Area of the proposed addition/alteration (from Step 2. above)

SD_a = Standard design for the proposed addition/alteration (from Step 2, above)

A_{e+a} = Area of the entire building after the proposed addition/ alteration

Step 4. Model the entire building, including the proposed addition/ alteration, along with any improvements to the existing building. If the proposed design is less than or equal to the energy use goal (from Step 3. above), the addition or alteration complies.

Example 3-10– Existing-plus-Additions Approach

Question

3,000 ft^2 of conditioned space is being added to an existing office building. 60% of the lights in the existing office space are being replaced with more efficient fixtures. Can credit be taken for the improved lights in the existing building to comply through the existing-plus-addition performance approach?

Answer

Credit can only be taken for lighting efficiency improvements resulting in a lower lighting power density than is required to meet §146 of the standards. Otherwise, credit may be taken for improvement(s) to the envelope component *only*. Lighting in the existing building must meet all prescriptive requirements in this case (more than 50% of the lights replaced or the connected load is increased).

Example 3-11– NFRC Label Certificate Scenarios

Question

The envelope and space conditioning system of an office building with 120,000 ft^2 of conditioned floor area is being altered. The building has 24,000 ft^2 of vertical fenestration. Which of the following scenarios does the NFRC label certificate requirement apply to?

1. Existing glazing remains in place during the alteration.
2. Existing glazing is removed, stored during the alteration period and then re-installed (glazing is not altered in any way).
3. Existing glazing is removed and replaced with new site-assembled glazing with the same dimensions and performance specifications.
4. Existing glazing on the north façade (total area 6000 ft^2) is removed and replaced with site-assembled fenestration.

Answer

NFRC label certificate requirement does not apply to scenarios 1, 2, and 4 but does apply to scenario 3.

1. Requirement does not apply because the glazing remain unchanged and in place.
2. Exception to §116(a) applies in this case (this exception applies to fenestration products removed and reinstalled as part of a building alteration or addition).
3. Label certificate requirement applies in this case as 24,000 ft^2 (more than the threshold value of 10,000 ft^2) of new vertical fenestration is being installed in 120,000 ft^2 of conditioned floor area (more than the threshold value of 100,000 ft^2).
4. Label certificate requirements do not apply because less than 10,000 ft^2 of vertical glazing is being replaced.

3.3 Envelope Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the recommended forms and procedures for documenting compliance with the envelope requirements of the *Standards.* It does not describe the details of the requirements; these are presented in Section 3.2 Envelope Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the building department plan checkers who are examining documents for compliance with the *Standards.*

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections.

ENV-1: Certificate of Compliance
This form should be required for every job, and it is required to appear *on the plans. (Title 24, Part 1, §10-103 of the California Code of Regulations.)*

ENV-2: Envelope Component Method, Overall Envelope Method, or Performance Method
One of these three versions should be part of every envelope compliance submittal. Choose the version that corresponds to the compliance method selected for the job.

ENV-3: Metal-Framed Assembly, Masonry Assembly, or Proposed Wood Frame Assembly

One of these forms should be submitted for each construction assembly in the building that does not use an Energy Commission default U-factor. The version is chosen to match the type of assembly. If the assembly is something other than a metal-framed or masonry assembly, the Proposed Construction Assembly version of ENV-3 should be used.

Cool Roofs

Prior to January 1, 2003, manufacturer's published performance data shall be acceptable to show compliance with minimum solar reflectance requirements for roofing products like concrete and clay tiles. Note that effective January 1, 2003 the label must be certified by the Cool Roof Rating Council (CRRC).

The performance data must include information on:

- Test method
- Date the test was performed
- Thickness (mil) for liquid applied products
- Solar reflectance
- Thermal emittance

For liquid applied roofing products, the following key properties must also be tested:

- Initial Tensile Strength
- Initial Elongation
- Elongation After 1000 Hours Accelerated Weathering
- Permeance
- Accelerated Weathering

Eligible tile cool roofs are roofs tested to have a solar reflectance of 0.4 or greater and a thermal emittance of 0.75 or greater (see 3.1.2H for details). Eligible single ply or liquid applied cool roofs are roofs tested to have a solar reflectance of 0.70 or greater and a thermal emittance of 0.75 or greater. Eligible liquid applied cool roofs will also have a thickness greater than 20 mils and meet minimum performance requirements.

3.3.1 ENV-1: Certificate of Compliance

The ENV-1 Certificate of Compliance form has two parts. Both parts must appear on the plans (usually near the front of the architectural drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the *Energy Commission's* forms), provided the information is the same and in similar format.

A. ENV-1 Part 1 of 2

Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

3. **PROJECT ADDRESS** is the address of the project as shown on the plans and known to the building department.

4. **PRINCIPAL DESIGNER - ENVELOPE** is the person responsible for the preparation of the building envelope plans, and who signs the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.

5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation and who signs the STATEMENT OF COMPLIANCE. The person's telephone number is given to facilitate response to any questions that arise.

6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

2. **BUILDING CONDITIONED FLOOR AREA** has specific meaning under the energy *Standards*. Refer to Section 2.2.1 for a discussion of this definition.

3. **CLIMATE ZONE** is the official climate zone number where the building is located. Refer to California Climate Zone Description (Appendix C) for a listing of cities and their climate zones.

4. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the *Nonresidential Standards* are designated "Nonresidential" here. It is possible for a building to include more than one building type, in which case check all applicable types here. See Section 2.2.1 for the formal definitions of these occupancies.

5. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2.2 for detailed discussion of the various choices.

   a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.2F), newly conditioned space (see Section 2.2.2B) or a stand-alone addition submitted for envelope compliance.

   b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses existing plus addition performance compliance, as described in Section 2.2.2E.

   c. **ALTERATION** should be checked for alterations to existing building envelopes. See Section 2.2.2D.

   d. **UNCONDITIONED** should be checked when the building is not intended as conditioned space, or when the owner chooses to defer demonstrating envelope compliance until such time as the space conditioning system permit application is submitted. See Section 2.2.2A for a full discussion. The building department may require the owner to file an affidavit declaring the building to be unconditioned and acknowledging that all the *Standards* requirements must be met when the building is conditioned.

6. **METHOD OF COMPLIANCE** - indicate which method is being used and documented with this submittal:

   a. **COMPONENT** for the Envelope Component Method

   b. **OVERALL ENVELOPE** for the Overall Envelope Method

   c. **PERFORMANCE** for the Performance Method

Statement of Compliance

The Statement of Compliance is signed by the person responsible for preparation of the plans for the building and the documentation author. This principal designer is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the *Business and Professions Code* (based on the edition in effect as of July 1998), referenced on the Certificate of Compliance are provided below:

5537. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person

Envelope Mandatory Measures

The Mandatory Measures should be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a note block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. A sample, generic envelope mandatory measures note block is shown in Example 3-12. This is offered as a starting point for designers; it should be incorporated into the organization of the plan set and modified to be specific to the building design.

Example 3-13– Sample Notes Block - Envelope Mandatory Measures

Installed Insulating Material

- ❑ Shall have been certified by the manufacturer to comply with the California Quality Standards for Insulating Material.

All Insulating Materials

- ❑ Shall be installed in compliance with the flame spread rating and smoke density requirements of Sections 2602 and 707 of the UBC.

All Exterior Joints

- ❑ All Exterior joints and openings in the building envelope that are observable sources of air leakage shall be caulked, gasketed, weather-stripped or otherwise sealed.

Site Constructed Doors, Windows and Skylights

- ❑ Shall be caulked between the unit and the building, and shall be weather-stripped (except for unframed glass doors and fire doors).

Manufactured Doors and Windows

- ❑ Manufactured doors and windows installed shall have air infiltration rates certified by the manufacturer per §116(a)1. Manufactured fenestration products must be labeled for U-factor according to NFRC procedures.

Demising Wall Insulation

- ❑ Demising wall insulation shall be installed with R-11 in all opaque portions of framed walls (except doors).

B. ENV-1 Part 2 of 2

The information on Part 2 summarizes the information about the building envelope that can be readily verified by the building department field inspector. This form should be included on the plans. Alternatively, the information may be incorporated into construction assembly and glazing schedules on the plans, provided it is complete and in substantially the same format as this form.

Opaque Surfaces

1. **SURFACE TYPE** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **CONSTRUCTION TYPE** - list the general type of construction for each opaque surface type. The entry should be descriptive, as it is used by the field inspector to distinguish between the various assemblies.

3. **AREA** - list the gross surface area of the surface type.

4. **U-FACTOR** - list the U-factor of the surface type.

5. **AZIMUTH** - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

6. **TILT** – Tilt of opaque surface is expressed in terms of degrees, 0=horizontal facing up, 90=vertical, 180=horizontal facing down.

7. **SOLAR GAINS Y/N** - indicate Y[yes] for opaque surfaces that will be receive direct or indirect sunlight.

8. **FORM 3 REFERENCE** - list the name used on the ENV-3 form for the proposed assembly (whether or not it is a default value).

9. **LOCATION/COMMENTS** - use to provide further description for each surface type. Again, it should be descriptive to assist in locating and inspecting the assembly.

10. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Site Assembled Glazing – Indicate by checking off box if building is greater than or equal to 100,000 sf^2 of CFA and greater than or equal to 10,000 sf^2. NFRC Certification is required. Follow NFRC 100-SB Procedures and submit NFRC Label Certificate form with submittal.

Fenestration Surfaces

1. **FENESTRATION TYPE** - provide a designator for each unique type of window.(e.g., window, skylight).

2. **AREA** - indicate the total square feet of all of the fenestration with the same characteristics.

3. **U-FACTOR** - indicate the maximum U-factor for windows using either manufacturer's data or the Energy Commission's default U-factors (See Section 3.1.2I).

4. **AZIMUTH** - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

5. **SHGC** - list the solar heat gain coefficient (SHGC) of the fenestration product using either manufacturer's data or the Energy Commission's default SHGC values (see Table 3-12). Or use the alternative calculation procedure for Nonresidential Solar Heat Gain Coefficients (see Appendix B Table 12). This method is only used to calculate SHGC values. A SHGC center of glass alone value is required to be used with equations listed in Table 12. See 3.1.2J.

6. **GLAZING TYPE** - indicate the general type of primary glazing material for the window (clear, tinted, reflective, low-e, etc.).

7. **LOCATION/COMMENTS** - use to provide further description for each surface type. It should be descriptive enough to assist in locating and inspecting the fenestration.

8. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Exterior Shading

(Note that 'SHGC' and 'fins' apply to performance approach only).

1. **Fenestration** # - list the designation on the plans for the fenestration with exterior shading.

2. **Exterior Shade** Type - list the type of exterior shading, limited to devices permanently attached to the building (e.g., shade screens), or structural components of the building (i.e., overhangs and fins). Manually operable shading devices cannot be modeled.

3. **SHGC** - list the Solar Heat Gain Coefficient of the shading device. For Performance use only.

4. **Window** - when the shading type is an overhang or fin list the height and width (in feet) of the window.

5. **Overhang** - for overhangs being used to achieve compliance with prescriptive envelope requirements, list the dimensions (in feet) of the overhang:

   a. **Length** - is the distance (in feet) the overhang projects out from the building facade.

   b. **Height** - is the distance, in feet, from the bottom of the window to the bottom of the overhang. To qualify for credit, the bottom of the overhang must be no more than two vertical feet higher than the top of the window (window head).

LExt. and **RExt**. - is the length the overhang extends beyond the window on the left and right sides. Credit for an overhang may be taken only if the overhang extends beyond both sides of the window jamb a distance equal to the overhang length.

For Performance use only;

Left Fin – dimension which describes side fins to the left of the fenestration in feet-inches.

a. Distance along the wall from the left edge of the glazing. b. Length of the left fin from the wall, from the length field in the fins.

c. Height of the left fin from the bottom of the wall to the top of the fin.

Right Fin – dimension which describes side fins to the right of the fenestration in feet-inches.

a. Distance along the wall from the right edge of the glazing.

b. Length of the right fin from the wall, from the length field in the fins.

c. Height of the right fin from the bottom of the wall to the top of the fin.

Notes to Field

This space is for building department use only. It may be used by the plan checker to continue or elaborate on notes elsewhere on the form.

3.3.2 ENV-2: Envelope Component Method

This form (ENV-2) should be used only when the envelope is shown to comply using the Envelope Component Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Window Area Calculation

This calculation determines whether the window area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **GROSS WALL AREA** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits.

2. **DISPLAY PERIMETER** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 6 to determine the display perimeter area for glazing limits.

3. **MAXIMUM ALLOWABLE WINDOW AREA** - the greater of the previous two calculation results is the maximum window area allowed under the Envelope Component Method.

4. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowable Window Area, then the Envelope Component Method may not be used.

B. Skylight Area Calculation

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2A for definition and discussion.

2. **ALLOWED %** - Depending on the atrium height, the allowed percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - Gross roof area - refer to Section 3.1.2A for definition and discussion.

4. **ALLOWABLE SKYLIGHT AREA** - Allowed Skylight Area - the maximum allowable skylight area is the product of the previous two numbers.

5. **ACTUAL SKYLIGHT AREA** - Actual Skylight Area - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowed Skylight Area, then the Envelope Component Method may not be used.

C. Opaque Surfaces

1. **ASSEMBLY NAME** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **TYPE** - provide the type of assembly as described in Table 3-22 and Table 3-23 (e.g. wood- frame wall, other floor/soffit, etc.). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly shown in Table B-7, e.g. R.30.2 x 10.16, in the "Opaque Surfaces" category.

3. **HEAT CAPACITY** - see Section 3.1.2G for discussion of how this value is found. For light-weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies, but if it is blank, the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

4. **INSULATION R-VALUE** - This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Assembly U-factor option is used, this space may be left blank. The PROPOSED value is the R-value for the insulation product alone, not the total R-value for the assembly. It must be consistent with the R-value called out on the ENV-1 form. The MIN. ALLOWED value is taken from Table 3-22 and Table 3-23.

5. **ASSEMBLY U-FACTOR** - This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Insulation R-value option is used, this space may be left blank. The PROPOSED value is taken either from an Energy Commission table of defaults, or is calculated on the appropriate ENV-3 (see Appendix B) and Sections 3.1.2C - F . If a default table value is used, check the “Y” (yes) box. If a calculated value is used, check the “N” (no) box and attach the corresponding ENV-3 form. The ALLOWED value is taken from Table 3-22 and Table 3-23.

D. Windows

1. **WINDOW NAME** - provide a name or designator for each unique type of window. This designator should be used consistently throughout the plan set (elevations, window schedules, etc.) to identify each window. It should also be consistently used on the other forms in the compliance documentation.

2. **ORIENTATION -** indicate orientation (see Section 3.1.2A for definitions) of each unique type of window. A window with an overhang and a similar window without an overhang would be different types. If overhangs are not used, similar windows on non-north orientations may be grouped together.

3. **U-FACTOR** - PROPOSED glazing U-factor is determined as discussed in Section 3.1.2I. ALLOWED U-factor is taken from Table 3-22 and Table 3-23.

4. **NO. OF PANES** - indicate “2” for double glazed, “1” for single glazed windows.

5. **PROPOSED RSHG** – indicate SHGC (Solar Heat Gain Coefficient), OHF (Overhang Factor), and the resulting RSHG (RSHG = SHGCwin x [1 + aH/V + b(H/V)^2]).

See Sections 3.1.2I and 3.1.2J. If given window does not have an overhang, then SHGC and RSHG are the same.

6. **ALLOW. RSHG** - the Maximum Relative Solar Heat Gain allowed, taken from Table 3-22 and Table 3-23, depending on the window orientation (north or non-north).

E. Skylights

1. **SKYLIGHT NAME** - provide a name or designator for each unique type of skylight. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each skylight. It should also be consistently used on the other forms in the compliance documentation.

2. **GLAZING** - indicate if glazing has curb or no curb. Indicate if the glazing is made of glass or plastic. This affects the allowed solar heat gain coefficient.

3. **NO. OF PANES** - indicate, "2" for double glazed, "1" for single glazed skylights.

4. **U-FACTOR** - PROPOSED glazing U-factor is determined as discussed in Section 3.1.2I. ALLOWED U-factor is taken from Table 3-22 and Table 3-23.

5. **SOLAR HEAT GAIN COEFFICIENT** - indicate PROPOSED solar heat gain coefficient. See Section 3.1.2J. The ALLOWED value is the Maximum Solar Heat Gain Coefficient taken from Table 3-22 and Table 3-23, depending on the type of glazing (made of glass or plastic).

3.3.3 ENV-2: Overall Envelope Method

This version of ENV-2 should be used only when the envelope is shown to comply using the Overall Envelope Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. ENV-2 Part 1 of 6

The first part of this form involves tests of glazing area for windows and skylights. If either of these tests does not pass, then the glazing area must be adjusted for the standard envelope.

Window Area Test

A. **DISPLAY PERIMETER** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 6 to determine the DISPLAY AREA for glazing limits.

B.-D. **GROSS EXTERIOR WALL AREA** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits, and by 0.1 to determine the minimum area for glazing limits. The larger of the DISPLAY AREA and the 40% AREA is the MAXIMUM AREA.

E. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculations, then the window area will be adjusted for the standard envelope. Otherwise, the window calculations on Parts 2 through 5 can be done without adjusted window or wall areas. Proceed to the SKYLIGHT AREA TEST.

1. or 2. **WINDOW ADJUSTMENT FACTOR** - if E is greater than D or less than C, one of these two calculations is done to obtain the WINDOW ADJUSTMENT FACTOR. This number is carried to Part 6 of the form to calculate the adjusted window and wall areas. Upon completion of those calculations, Part 2, Part 3, and Part 5 may be completed.

Skylight Area Test

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Standard Envelope.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2A for definition and discussion.

2. **STANDARD %** - depending on the atrium height, the allowed standard percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - gross roof area - refer to Section 3.1.2A for definition and discussion.

4. **STANDARD SKYLIGHT AREA** - the maximum allowed standard skylight area is the product of the previous two numbers.

5. **PROPOSED SKYLIGHT AREA** - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculation, then the skylight area will be adjusted for the standard envelope. Otherwise, the skylight calculations on Part 2, Part 3, and Part 5 can be done without the adjusted skylight or roof areas.

1. or 2. **SKYLIGHT ADJUSTMENT FACTOR** - this calculation is done to obtain the SKYLIGHT ADJUSTMENT FACTOR. This number is carried to Part 6 of the form to calculate the adjusted skylight and roof areas. Upon completion of those calculations, Parts 2 through 5 may be completed.

B. ENV-2 Part 2 of 6 Overall Heat Loss

This form should be used to confirm that the proposed envelope design has an overall heat loss no greater than the standard heat loss for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate “2” for double glazed, “1” for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2.A for definitions and discussion.

C. **PROPOSED HEAT CAPACITY -** see Section 3.1.2G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

D. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C - F and Sections 3.3.4 through 3.3.6).

TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

E. **PROPOSED UA** - the numbers in columns B and D are multiplied together and the result entered in this column.

F. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED

AREA for each assembly. If adjustments are required, then the adjusted areas of window, wall, skylight and roof are taken from Part 6.

G. **STANDARD U-FACTOR** - enter the Maximum U-factor for each assembly type, taken from Table 3-22 and Table 3-23*.* The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

H. **STANDARD UA** - the numbers in columns F and G are multiplied together and the result entered in this column.

Columns E and H are totaled and the results compared. If the Column E total is no greater than the Column H total, then the Overall Heat Loss requirement has been met.

C. ENV-2 Part 3 of 6 Overall Heat Gain from Conduction

This form should be used to confirm that the proposed envelope design has an overall heat gain from opaque surfaces no greater than the standard heat gain for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate “2” for double glazed, “1” for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2A for definitions and discussion.

C. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and Climate Zone from Table 3-24 or *Standards* Table No. 1-J. For glass and skylight assume Light Mass.

D. **PROPOSED HEAT CAPACITY -** see Section 3.1.2.G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

E. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C through 3.1.2F and Sections 3.3.4 through 3.3.6), or from EZ-FRAME output.

TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

F. **HEAT GAIN Q** - the numbers in columns B, C and E are multiplied together and the result entered in this column.

G. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 6.

H. **STANDARD U-FACTOR** - enter the Maximum U-factor for each assembly type, taken from Table 3-22 and Table 3-23*.* The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

I. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and climate zone from Table 3-24 or *Standards* Table No. 1-J. For glass and skylight assume Light Mass.

J. **HEAT GAIN Q** - the numbers in columns G, H and I are multiplied together and the result entered in this column.

Columns F and J are totaled and the results compared. These subtotals are entered under 'Part 3 Subtotal' in columns I and M of ENV-2 Part 5 of 6.

D. ENV-2 Part 4 of 6 Overall Heat Gain from Radiation

This form should be used to confirm that the proposed envelope design has an overall heat gain no greater than the standard heat gain for the opaque surfaces of the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of roof surface (e.g., Roof-1, Roof-2, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. **AREA** - enter the actual area, in square feet, of each assembly. Refer to 3.1.2A for definitions and discussion

C. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

D. **WEIGHTING FACTOR** - enter the appropriate weighting factor based on climate zone and weighting factors. $WFG_{G,}$ for glazing, $WF_{R,}$ for roof and $WF_{S\ for}$ skylight, each

E. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B)

F. **PROPOSED ABSORPTIVITY** (α)- Enter the absorptivity of the proposed roof assembly (use an absorptivity of 0.45 for cool roofs and an absorptivity of 0.7 for all other roofs).

G. **PROPOSED HEAT GAIN** - the numbers from columns B, C, D, E, and F are multiplied and entered in this column.

H. **AREA (ADJUSTED)** - if no skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each roof assembly. If adjustments are required, then the adjusted areas of skylight and roof are taken from Part 6.

I. **STANDARD U-FACTOR** - enter the Maximum U-factor for each roof assembly, taken from Table 3-22 and Table 3-23. The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

J. **STANDARD ABSORPTIVITY** (α)-Enter the absorptivity of the standard roof assembly (0.70).

K. **STANDARD HEAT GAIN -** multiply columns C, D, H, I, and J and enter the result here.

Columns G and K are totaled. These subtotals are entered under 'Part 4 Subtotal' in columns I and M of ENV-2 Part 5 of 6.

E. ENV-2 Part 5 of 6 Overall Heat Gain from Radiation

This form should be used to confirm that the proposed envelope design has an overall heat gain no greater than the standard heat gain for fenestration for the building and summarizes the heat gain from opaque surfaces and fenestration.

A. **WINDOW/SKYLIGHT NAME** - provide a name or designator for each orientation of glazing under the appropriate heading (NORTH, SOUTH, SKYLIGHTS, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. **WEIGHTING FACTOR** - enter the weighting factor for each orientation and skylight. The weighting factors are taken from Table 3-25 or *Standards* Table No. 1-K, and depend on the climate zone (from ENV-1, Part 1).

C. **PROPOSED AREA** - the total area of proposed windows and skylights shown on the plans is entered here. See Section 3.1.2A for definitions and discussion.

D. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

E. **PROPOSED SHGC** - the proposed solar heat gain coefficient of the glazing. See Section 3.1.2J.

F.-H. **PROPOSED OVERHANG** - indicate the overhang horizontal length (H), the overhang vertical height (V); overhang ratio (H/V); and overhang factor (OHF). Column F includes both (H for horizontal) and (V for vertical). See Section 3.1.2N. The overhang adjustment does not apply to skylights.

I. **PROPOSED TOTAL** - multiply columns B, C, D, E & H and enter the result here.

J. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 6.

K. **STANDARD RSHG** - this is the Maximum Relative Solar Heat Gain (RSHG) taken from Table 3-22 and Table 3-23 depending on the window orientation (north or non-north). The Maximum Solar Heat Gain Coefficient (SHGC) for skylights is taken from the same table, depending on whether the skylight glazing is made of glass or plastic. Note skylight must use SHGC and RSHG value is not allowed.

L. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

M. **STANDARD TOTAL -** multiply columns B, J, K & L and enter the result here.

Columns I and M are totaled, Totals from Columns F and J from Part 3 of 6 and Part 4 of 6 are carried forward and added, and the results compared. If the Column I total is no greater than the Column M total, then the Overall Heat Gain requirement has been met.

F. ENV-2 Part 6 of 6 Window Area Adjustment Calculations

This form should be included with all compliance submittals. If the WINDOW AREA TEST or the SKYLIGHT AREA TEST (Part 1 of this form) determines that area adjustments are not necessary, check the NOT APPLICABLE boxes. If the tests indicate that adjustments must be made, perform the calculations in the appropriate sections below.

A. **WALL NAME** - provide a name or designator for each unique type and orientation of wall that contains windows (walls without windows will have no adjustment). If an orientation has two different wall types, list each separately. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. See Section 3.1.2A for a discussion of orientation.

B.-D. **AREAS** - list the areas (in square feet). See 3.1.2A for definitions of these areas. The GROSS AREA is the Gross Exterior Wall Area for the particular wall type and orientation under consideration. The DOOR AREA and WINDOW AREA are for doors and windows included in each wall.

E. **WINDOW ADJUSTMENT FACTOR** is calculated on the top half of Part 1. It is the same for all windows in the building.

F. **ADJUSTED WINDOW AREA** is calculated by multiplying the values in Columns D and E.

G. **ADJUSTED WALL AREA** is calculated by subtracting B from the sum of C and F. If this produces a negative value enter zero.

Add Columns B, C, D, F and G. As a check, the total of Column B should equal the sum of the totals of Columns F & G.

The total in Column G is used in Column F of the Overall Heat Loss calculation (Part 2) and Column I of the Overall Heat Gain from Conduction calculation (Part 3) and the values in Column F are used in Column G of the Overall Heat Gain from Radiation calculation (Part 5).

Skylight Area Adjustment Calculations

A. **ROOF NAME** - provide a name or designator for each unique type of roof that contains skylights (roofs without skylights will have no adjustment). If an orientation has two different roof types, list each separately. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B.-C. **AREAS** - list the areas (in square feet). See Section 3.1.2A for definitions of these areas. The GROSS AREA is the Gross Exterior Roof Area for the particular roof type and orientation under consideration; note that it does not include doors, such as roof hatches. The SKYLIGHT AREA is for skylights included in each roof.

D. **SKYLIGHT ADJUSTMENT FACTOR** is the Skylight Adjustment Factor calculated on the bottom half of Part 1. It is the same for all skylights in the building.

E. **ADJUSTED SKYLIGHT AREA** is calculated by multiplying the values in columns C and D.

F. **ADJUSTED ROOF AREA** is calculated by subtracting E from B. If this results in a negative value enter zero.

Columns B, C, E and F are added. As a check, the total of Column B should equal the sum of the totals of Columns E and F.

The totals in Columns E and F are used in Column F of the Overall Heat Loss calculation (Part 2) and in Column G of the Overall Heat Gain from Conduction calculation (Part 3), and the values in Column E are used in Column I of the Overall Heat Gain from Radiation calculation (Part 5).

3.3.4 ENV-3: Proposed Metal Framed Assembly

For most metal framed assemblies, the U-factor will be found in Table B-2 in Appendix B (see Section 3.1.2E for a discussion of the use of this table). When there is no appropriate U-factor in Table B-2, then this version of ENV-3 should be used to calculate the assembly U-factor.

[Note that this form is not used to describe metal furring systems for insulating masonry or concrete walls; these are described in ENV-3 Masonry Assemblies.]

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note that the outside of the assembly, facing unconditioned space, is at the left.

2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.

3. **ASSEMBLY TYPE** - check the appropriate box.

4. **FRAMING MATERIAL** - must be metal for this form (other versions of ENV-3 are for other framing materials).

5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 3 1/2", 5 1/2", or other appropriate description.

6. **INSULATION R-VALUE** - enter the R-value of the insulation material in the assembly. If there is more than one insulation material, list each separately.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the wall that does not contain framing members) is calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.
2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer. This value is taken from manufacturers' literature or from the *ASHRAE Handbook of Fundamentals Volume, 1993,* Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials.* The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.
3. **METAL FRAMING FACTOR (MFF)** - enter the appropriate value for the assembly from Table 3-3 (Appendix B, Table B-3), or the table on the form.
4. **Rc X MFF** - multiply the SUBTOTAL R-value (R_c) for the cavity by the METAL FRAMING FACTOR and enter the result.
5. **INSULATING SHEATHING -** if there is a layer of insulating sheathing (other than the cavity insulation between the framing members), enter its R-value. Only values from *ASHRAE Handbook of Fundamentals Volume, 1993,* Table 3a, Chapter 23, may be used.
6. **TOTAL R-VALUE (R_t)** - add the previous two numbers and enter the result here.
7. **ASSEMBLY U-FACTOR** - divide 1 by the TOTAL R-VALUE (R_t) to obtain the ASSEMBLY U-FACTOR.

COMMENTS may be added to further explain the assembly or its U-factor calculation. This would be especially helpful for unusual assemblies, and could help to expedite plan checking for energy compliance.

3.3.5 ENV-3: Proposed Masonry Wall Assembly

This version of ENV-3 should be used for masonry wall assemblies (including concrete block, brick and solid concrete). It is used in conjunction with Tables B-4 and B-5 in Appendix B, which give U-factors and heat capacities for most common assemblies. It should also be used to account for the insulating qualities of insulating sheathing and/or furred sheathing layers attached to the masonry. Refer to Section 3.1.2F for further description of these calculations.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of any furring members and sheathing layers should be apparent. Note that the outside of the assembly, facing unconditioned space, is at the left.

2. **WALL ASSEMBLY NAME** - list the name or designator for this wall assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, or some other naming convention appropriate to the construction document organization.

3. **DESCRIPTION OF ASSEMBLY** - provide a brief description of the materials used in the assembly to augment the sketch.

B. Wall R-value and Heat Capacity

This section is used to extract values of wall R-value and heat capacity from Tables B-4 or B-5 in Appendix B.

1. **WALL UNIT THICKNESS** - enter the nominal thickness, in inches, of the masonry wall.

2. **MATERIAL TYPE** - enter the material type. For concrete block, this can be “light weight”, “medium weight”, or “normal weight” as per ASTM designations.

3. **CORE TREATMENT** - this is only applicable to hollow core masonry units; the choices are solid grouted cores, or partially grouted cores with the unfilled cells either empty or filled with any type of insulation.

4. **WALL R-VALUE (R_w)** - for hollow masonry, use Table B-4; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate R-value and enter it here (see Section 3.1.2F for more discussion).

5. **WALL HEAT CAPACITY (HC)** - for hollow masonry, use Table B-5; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate HC value and enter it here (see Section 3.1.2G for more discussion).

C. Furring/Insulation Layer

This section is used to describe any furring/insulation layers or insulating sheathing attached to either the inside or the outside of the masonry.

1. **FURRING FRAMING MATERIAL** - list the type of material (wood, metal) used for the furring strips; if not applicable enter "none".

2. **FURRING FRAMING SIZE** - enter the thickness, width, and depth, in actual inches, of the framing members used for furring, and its actual dimensions in inches.

3. **FURRING SPACE INSULATION** - enter the type of insulation installed in the space between furring strips (fiberglass batt, bead board, etc.), and its R-value at the installed thickness.

4. **EXTERIOR INSULATING LAYER** - if there is an exterior insulating layer, list the type of insulation (bead board, polyisocyanurate board, etc.), and its R-value at the installed thickness.

5. **FURRING ASSEMBLY EFFECTIVE R-VALUE** - using the information above, enter Table B-6 and locate the effective R-value of the furring assembly (see Section 3.1.2F).

6. **INSULATION LAYER R-VALUE (R_f)** - add the FURRING ASSEMBLY EFFECTIVE R-VALUE to the R-value of the exterior insulating layer to arrive at the INSULATION LAYER R-VALUE (R_f).

D. Wall Assembly R-value and U-factor

1. **WALL ASSEMBLY R-VALUE (R_t)** - add the INSULATION LAYER R-VALUE calculated above (R_t) to the WALL R-VALUE (R_w) from above to obtain the WALL ASSEMBLY R-VALUE.

2. **WALL ASSEMBLY U-FACTOR** - calculate the inverse of the WALL ASSEMBLY R-VALUE ($1/R_t$) to obtain the WALL ASSEMBLY U-FACTOR.

3.3.6 ENV-3: Proposed Wood Frame Assembly

This version of ENV-3 should be used for any construction assembly that is not found in the tables in Appendix B or appropriate for the metal framed or masonry versions of ENV-3. This form guides the user through the basic U-factor calculation, the Parallel Path Method (discussed in Section 3.1.2D), and the heat capacity calculation (see Section 3.1.2G). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, the "Reference Name" for the appropriate assembly is entered into either Form ENV-2 "Envelope Component Method" or ENV-2 Part 2 "Overall Envelope Method", whichever is applicable for the compliance method that the designer has selected. Refer to the specific sections in the Manual which provide instructions for filling out the respective forms, as to how the Reference Name of the assembly should be entered.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note the outside of the assembly, facing unconditioned space, is at the left of the sketch.

2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.

3. **ASSEMBLY TYPE** - check the appropriate box.

4. **FRAMING MATERIAL** - with this form framing material is wood only (other versions of ENV-3 are for other materials).

5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 2x4, 4x8, or other appropriate description.

6. **FRAMING PERCENTAGE** - choose the appropriate value from the small table to the right. For example, a floor assembly with joists spaced 24" on center (o.c.) would have a framing percentage of 7%.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the assembly that does not contain framing members) and the R-value of the assembly through the wood framing are calculated. The U-factor of the assembly is also calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.

2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer at a cross-section taken through the cavity. This value is taken from manufacturer's literature or from *the ASHRAE Handbook of Fundamentals Volume, 1993,* (Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials*) data reproduced in Appendix B, Table B-1. The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.

3. **WOOD FRAME R-VALUE (R_f)** - enter the R-value of each layer at a cross-section taken through a framing member. These values are found in the same sources cited in the previous paragraph.

4. **HEAT CAPACITY (HC) -** As an option, the HC of the assembly may also be calculated, although for most framed assemblies the HC will be too low to be of significance (HC values of less than 7 are not given any special consideration under the *Standards*).

5. **WALL WEIGHT -** enter the weight of each layer of the assembly, per square foot of the material at its given thickness. This is calculated from the density of the material, which is given in pounds per cubic foot. They may be taken from manufacturers literature or other standard reference works, such as the *ASHRAE Handbook of Fundamentals Volume, 1993*, Chapter 22 Table 4 (Appendix B). Dividing the density by 12 and multiplying by the material thickness (in inches) yields the WALL WEIGHT. For the framing material, the weight of the framing members must be converted to a pounds per square foot value.

6. **SPECIFIC HEAT** - enter the specific heat of each material, in Btu/°F-lb. These values are also found in ASHRAE Table 4 (see previous paragraph).

7. **HC** - columns A and B are multiplied together to obtain the heat capacity for each layer of the assembly.

8 **SUBTOTALS** - both R-value columns are summed. If calculated, the HC column is also summed to obtain the TOTAL HC for the assembly.

9. **ASSEMBLY U-FACTOR** - the appropriate values from above on this form are entered into the equation and the result calculated. Rc is the subtotal of the CAVITY R-VALUE column; R_f is the subtotal of the WOOD FRAME R-VALUE column. Fr% is the FRAMING PERCENTAGE. Care should be taken to recognize the parentheses in the calculation.

3.4 Envelope Inspection

The envelope building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the ENV-1 Certificate of Compliance, or a similar form, that must be printed on the plans (see Section). Included on the ENV-1 are “Notes to Field” which are provided by the plan checker to alert the inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I. Fenestration May require inspection of labels or label certificates. See Section 3.1.2M